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Full Length Research Paper

Improving hybrid cotton profitability and micronaire with stripcropping of soybean+pigeon pea with conservation furrows, Mn and B application

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Micronutrients and supplemental irrigations were evaulated in split plot design to improve hybrid cotton micronaire in last picking. Farmer's practices (FP) of sole hybrid cotton, soybean+pigeon pea (4:1) and cotton + pigeon pea (8:2) stripcroppings were compared alongwith soybean as intercrop in the existing cotton+pigeonpea stripcropping (8:2) for micronutrient requirement, rain water conservation and profitability. Soybean cultivation is best suited and most profitable in shallow soils of <0.45 m deep. Novel strip cropping of cotton + soybean + pigeon pea (4:4:2) alongwith opening of conservation furrow in pigeon pea with a profitability of 41 and 58% over sole cotton in shallow and medium deep soils. Micronutrients requirement was not arise with moderate cotton yield levels of sole and strip cropped cotton as INM application 5 t FYM ha^{-1} year^{-3}, compared to its absence in farmer's fields improved 15 to 35% seed cotton yield in Bt hybrid cotton under rainfed and two supplemental irrigations. Significant responses were observed for supplemental irrigations in low rainfall years alongwith Mn, B application in improving micronaire, seed cotton yield and profitability. Premium range of cotton micronaire was produced in last pick under rainfed and two supplemental irrigations in shallow and medium soils by Mn and B at 0.5 and 0.3% foliar spray 3 times after square initiation at fortnightly interval. Soil application of $MnSO_4$ at 25 kg ha^{-1} year^{-3} and Borax at 10 kg ha^{-1} year^{-3}, respectively in rainfed calcareous shallow and medium deep soils along with supplemental irrigations could improve micronaire.

Key words: Boron, conservation furrow, hybrid cotton, manganese, medium deep soils, micronaire, pigeon pea, profitability, strip cropping, soybean, shallow soils, supplemental irrigations.

INTRODUCTION

Boron and winter irrigations were suggested in coarse textured low water holding capacity soils for improving the lint yield, which produced variable fibre quality results across seasons lead to limited agronomical value (Bradow and Davidonis, 2000; Ahmed et al., 2012). Medium staple, long duration *Gossypium hirsutum* cotton hybrids were well adopted in rainfed *vertisols* 1972-2002 (Gruere and Sun, 2012). They had lower micronaire and strength with inefficient pink bollworm control in later pickings gave 25% lower profit realization by the farmers of central India (Sreenivasan and Venkata krishnan, 2007; Stone, 2007).

Winter flowering often caught in reduced atmospheric humidity, soil moisture and nutrients uptake under

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Abbreviations: **ICAR,** Indian Council of Agricultural Research; **LGP,** length of growing period; **VJAS,** Vidarbha Jan Andolan Samiti; **NGO,** Nagpur.

minimum temperatures 8°C during fibre elongation (Figure 2) results in lower micronaire and bundle strength in later pickings (Davidonis et al., 2004; Avgoulas et al., 2005; Wang et al., 2009; Yeates et al., 2010).

Supplemental irrigations or excess rains may further delay the maturity of cotton due to late production of bolls which reduces their micronaire and fibre strength (Brooker et al., 2006). Medium duration, long staple BT hybrid cotton introduction in 2002 to 2012 contributed by 19% yield improvement with 92% replacement of long duration medium staple *G. hirsutum* cotton hybrids and created shortages, which doubled their minimum support price (CAB, 2012; Gruere and Sun, 2012). Soils of central India were deficient in Zn, Fe and B which are required for the growth and development of cotton fibres and produced 5 to 16% higher lint yield (Dordas, 2006;Singh et al., 2008; Singh, 2012). Present research was conducted aiming at improving the profitability of cotton cultivation by improving micronaire in the later pickings through rain water conservation by stripcropping with soybean and pigeon pea (with conservation furrow) or winter irrigations with micronutrients as soil and foliar applications to shallow and medium deep soils.

MATERIALS AND METHODS

Study site

Experimental site was mild sloppy, medium deep *Vertisol*, Nagpur, India (21° 09'N 79° 09'E,). Nagpur has a tropical savanna climate (Köppen Aw) where cotton crop receives on an average 852 mm rainfall in 48 rainy days during June to October (Figure 1) in the past 115 years. Fluctuations in onset of monsoon rains with a seedling drought of 14 to 29 days was uncommon (Figure 1) and causing distress among Bt hybrid cotton farmers over repeated crop failures in central India (VJAS, 2011). Winter lasts from November to January, during which temperatures can drop below 10°C. Soil analysis found depth was <0.5 and 0.7 m, soil textural class clay loam, pH 8.1, organic carbon 0.4%, available N:P_2O_5:K_2O 280: 15:300 kg ha^{-1}, DTPA extractable Zn 0.57, Mn 2.54 ppm and B 0.114 ppm (Table 1 and Figure 3).

Field experiments were conducted to find out a management strategy for improving micronaire and bundle strength in later pickings of medium staple long duration intra *G. hirsutum* hybrid cotton NHH 44 as it covered largest area in India at the time of introduction of Bt hybrid cotton in 2002. Input response and efficiency in the soybean-hybrid cotton system a 4 years rotation were studied during 2002 to 2004 and stripcropping with soybean and pigeon pea during 2005 to 2007. Micronutrient builtup, input response and fibre qualities were assessed after six years in shallow and medium deep soils. Seven nutrition management treatments were evaluated as main plots *viz*., Control, $ZnSO_4$ 25 kg ha^{-1} year^{-3}, Borax 10 kg ha^{-1} year^{-3}, $MnSO_4$ 25 kg ha^{-1} year^{-3}, $ZnSO_4$, Mn SO_4, Borax 2/3 rd soil application and 1/3 rd foliar application, Foliar application of Zn, Mn and B at 0.5 and 0.3% with and without 2% Urea at flowering and early boll development stage in rainfed and two supplemental winter irrigations as sub plots were evaluated in split plot design.

Micronutrients were applied 10 days after basal application of complex phosphatic fertilizers to avoid interaction as side dressing. Need based plant protection measures and other in medium deep soils and only one year in shallow soils, followed recommended package of practices were followed time to time. These treatments were initially tested in sole cotton 2002 to 2004 by prevailing stripcropping mode to findout further response and profitability for agronomical value with wider implications. Sole cotton was spaced at 0.75 x 0.75 m during 2002 to 2004 in both shallow and medium deep soils as it was a farmer's practice.

Stripcropped cotton and soybean were planted at 0.45 x 0.45 m, 0.45 x 0.10 m, respectively in a paired planting at 0.90/1.35 m in alternate rows. Pigeon pea was stripcropped 0.90 x 0.15 with soybean and 0.45 x 0.45 m in cotton, after 8 rows, that is, same spacing to that of main crop as followed by the farmers. Soil and cotton plant samples were analyzed as per standard procedures. Available soil zinc and manganese were estimated by DTPA extraction method by GBC, AAS and Boron was estimated by hot water soluble method. Mean maturity days were estimated from multiple cotton pickings and fibre properties were analysed by HVI 900 Zellweger Uster in ICC mode.

RESULTS AND DISCUSSION

Biomass production and maturity

Micronutrients nutrients application could not significantly change in cotton maturity (Table 2) or biomass production of soybean and pod yield in both pure and strip cropped soybean (Table 3). Shallow soils significantly produced higher soybean biomass, pod yield g plant^{-1} and grains pod^{-1} except pod weight g which was superior in medium deep soils in both pure and strip cropped soybean (Table 4). This was possible due to better aeration provided by sloppy, shallow soils under excess rains of July, August, 2006 (Figure 1). Therefore, the shallow soil resource should be better used for soybean crop of 100 days (LGP) for improving and stabilizing the profitability instead of growing 180 days duration hybrid cotton with a higher probability of crop failure in case of aberrant weather conditions (NBSS, LUP, 2013). Mn availability will be restricted in coarse texture calcareous soils with latent deficiency as observed in soil analysis (Table 1), therefore, soluble $MnSO_4$ 25 kg ha^{-1} year^{-3} soil application significantly improved biomass production t ha^{-1} (BMP) and pod yield g plant^{-1} in pure soybean (Singh, 2012). Significant improvements in BMP of soybean by Zn SO_4 25 kg ha^{-1} year^{-3} soil application brought in medium deep soils and Zn, $MnSO_4$ 25 and Borax 10 kg ha^{-1}year^{-3} micronutrients in shallow soils and foliar application of micronutrients along with 2% urea and also without urea on pod yield g plant^{-1} at flowering stage needs further verification for wider agronomical recommendations. Biomass production of soybean + cotton + pigeon pea strip cropping was significantly reduced by two supplemental irrigations in shallow soils when excess rains received in the year 2006 with uncontrolled weed growth (Figure 1).

Yield advantage and profitability

Proportion of cotton and soybean planting in central India

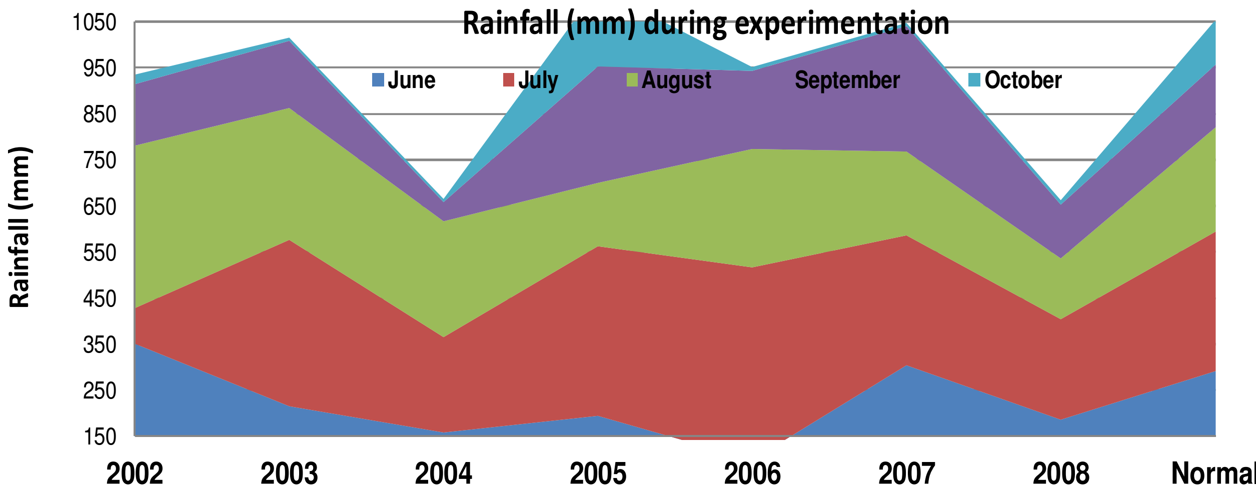

Figure 1. Monthly rainfall (mm) during experimentation.

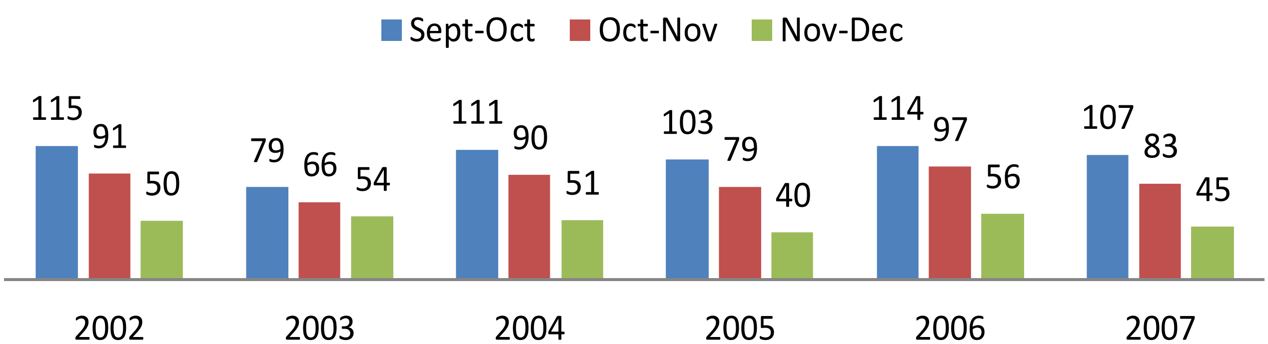

Figure 2. Mean temperature above base 15°C during boll development.

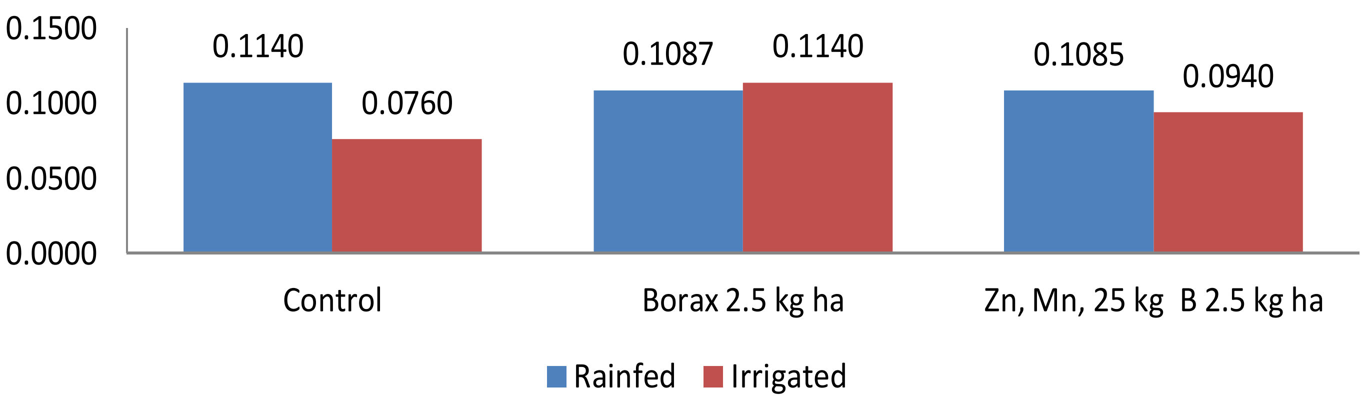

Figure 3. Boron content (ppm) after 6 years.

varies 40 to 60% of the farms area on year to year basis depends upon yield and price received in the previous monsoon season which depends on rainfall and pest incidence (Bhagawat, 2012). However, farmers feel there is double net returns/ Re investment on soybean due lower risks/ input costs unless severe semilooper or bollworms damage and weeds under excess rains may cause yield losses, respectively in cotton and soybean

Table 1. Zn, Mn status after 6 cycles of the cotton in medium deep soils.

Main plot treatment	Zn (ppm)						Mn (ppm)					
	20 cm			40 cm			20 cm			40 cm		
	I	R	Mean	I	R	Mean	I	R	Mean	I	R	Mean
Control	0.53	0.70	0.62	0.57	0.73	0.65	2.94	3.06	3.00	2.19	1.77	1.98
$ZnSO_4$ 25 kg ha^{-1} $year^{-3}$	0.71	1.12	0.92	1.76	1.89	1.83	2.79	3.61	3.20	2.85	2.25	2.55
$MnSO_4$ 25 kg ha^{-1} $year^{-3}$	0.49	0.75	0.62	0.62	2.03	1.32	3.37	2.14	2.75	2.60	5.59	4.1
Borax 10 kg ha^{-1} $year^{-3}$	0.47	0.58	0.53	0.51	0.63	0.57	1.23	4.82	3.03	2.22	1.93	2.08
Zn, $MnSO_4$ 25 Borax 10 kg ha^{-1} $year^{-3}$	0.62	0.91	0.76	1.17	0.38	0.78	2.86	2.20	2.53	2.34	2.33	2.33
Zn, Mn,B foliar spray at 0.5 and 0.3%	1.53	0.64	1.09	0.68	0.47	0.57	2.56	2.90	2.73	1.99	1.86	1.92
Zn, Mn,B foliar spray at 0.5 and 0.3% with 2% urea	0.68	0.61	0.65	0.84	0.57	0.71	4.10	3.04	3.57	2.39	2.59	2.49
Mean	0.72	0.76		0.88	0.96		2.84	3.11		2.37	2.62	
S.E.(m)±5%	0.27		0.15	0.96		0.36	0.96		0.36	0.8		0.26
CD 5 %	0.35		0.65	1.98		1.53	1.98		1.53	1.66		1.1

I = Two supplemental irrigations; R = Rainfed.

Table 2. Cotton crop maturity and biomass production t ha^{-1} in different soils.

Main plot treatment	Maturity days	Biomas production t ha^{-1}			Soybean pod yield g $plant^{-1}$			Pure soybean 2006	
		S	CSP	SPP	Pure	CSP	SPP	Grain g pod^{-1}	Pod wt g
Control	182	8.0	8.2	8.8	29.9	15.1	21.3	0.138	2.44
$ZnSO_4$ 25 kg ha^{-1} yr^{-3}	183	7.9	6.8	7.8	24.0	14.4	14.1	0.166	2.48
$MnSO_4$ 25 kg ha^{-1} yr^{-3}	183	10.1	8.3	10.2	26.8	20.5	22.3	0.149	2.27
Borax 10 kg ha^{-1} yr^{-3}	180	7.8	7.3	7.1	21.3	17.3	15.7	0.172	2.23
Zn, $MnSO_4$ 25 Borax 10 kg ha^{-1} yr^{-3}	186	9.2	9.4	8.0	19.5	15.3	12.7	0.133	2.23
Zn, Mn,B foliar spray @ 0.5 and 0.3%	180	11.1	9.6	8.5	32.9	17.3	17.1	0.145	2.30
Zn, Mn,B foliar spray @ 0.5 and 0.3% with 2% urea	184	10.6	9.7	10.6	29.3	25.1	20.8	0.153	1.93
S.E.(m) ± 5%	3	1.1	1.8	1.1	6.4	5.5	3.7	0.03	0.31
Medium	186	8.1	7.7	8.0	19.9	13.0	14.3	0.142	2.60
Shallow	179	10.3	9.2	9.4	32.6	22.8	21.1	0.160	1.94
S.E.(m) ± 5%	4		0.9	0.8				0.02	
CD ± 5%		1.4			5.6	5.9	4.4		0.37
Irrigation	183	8.8	8.5	8.4	25.6	18.1	17.3	0.151	2.27
Rainfed	182	9.7	8.4	9.0	26.9	17.6	18.1	0.151	2.26
S.E.(m) ± 5%	2	0.6	0.6	0.6	2.1	1.7	2.0	0.01	0.10
Micronutrients x soils	4	1.7	1.7	1.5	8.2	4.5	5.2	0.02	0.27
CD ± 5%	9	3.5	3.4	3.2	16.7	9.2	10.8	0.05	0.56

Table 2. Contd.

Sig	NS	S	NS	NS	S	NS	NS	NS	NS
Micronutrients x Irrigations	8	1.7	2.1	1.8	7.6	6.0	5.3	0.03	0.38
S.E.(m) ± 5%	18	3.4	4.3	3.8	15.8	12.1	11.2	0.07	0.50
Soils x Irrigations	5	0.9	0.9	0.8	4.0	3.2	2.8	0.02	0.20
CD ± 5%	10	1.9	1.8	1.7	8.4	6.8	6.0	0.04	0.43
Sig	NS	NS	S	NS	NS	NS	NS	NS	NS
Micronutrients x soils x Irrigations	12	2.4	2.9	2.5	10.7	8.5	7.5	0.05	0.39
S.E.(m) ±5%	25	5.1	6.0	5.3	23.5	18.1	15.9	0.10	0.79

Note: S = Soybean, CSP = cotton + soybean + pigeon pea stripcropping, SPP = soybean + pigeon pea stripcropping, Pure = sole soybean.

Table 3. Interaction of micronutrients x soils on soybean biomass and pod yield plant during 2006.

Main plot treatment	Biomass production t ha^{-1} pure soybean		Pod yield g $plant^{-1}$ pure soybean	
	Medium	Shallow	Medium	Shallow
Control	8	8	24.3	35.5
$ZnSO_4$ 25 kg ha^{-1} $year^{-3}$	10.3	5.5	29.3	18.7
$MnSO_4$ 25 kg ha^{-1} $year^{-3}$	7.7	12.5	13.0	40.5
Borax 10 kg ha^{-1} $year^{-3}$	6.7	9	17.2	25.3
Zn, Mn SO4 25 Borax 10 kg ha^{-1} $year^{-3}$	7.7	10.7	9.3	29.7
Zn, Mn, B foliar spray at 0.5 and 0.3%	8.2	14	22.0	43.8
Zn, Mn, B foliar spray at 0.5 and 0.3% with 2% urea	8.5	12.7	24.0	34.5
CD ± 5%	3.5		16.7	

Table 4. Interaction of supplemental irrigations x soils on soybean biomass t ha^{-1} cotton+ soybean strip cropping during 2006.

	Two supplemental irrigation	Rainfed
Medium	8.43	8.57
Shallow	6.95	9.91
CD ± 5%	2.9	

crops. Cotton + soybean + pigeon pea strip cropping in 4:4:2 ratio without change in planting and interculture implements (0.45 m apart) could give 41 and 54% more profit in shallow and medium deep soils by opening a conservation furrow at pigeon pea rows (Table 5). It is

Table 5. Sole and strip cropping of cotton and soybean yield and profitability in shallow soils.

Sole cropping	Mean	Stripcropping	Mean	Probability
Seed cotton yield kg ha^{-1}	1138	Cotton+soybean+pigeon pea intercropped cotton yield kg ha^{-1}	897	0.00002
Net profitability Rs/Re investment	0.93	Net profitability	1.32	0.00012
Soybean yield kg ha^{-1}	2186	Soybea+pigeonpea stripcropping soybean yield kg ha^{-1}	1499	1.2E-07
Net profitability Rs/Re investment	2.57	Net profitability	2.10	0.00013

Table 6. Sole and strip cropping of cotton and soybean yield and profitability in medium deep soils.

Sole cropping	Mean	Stripcropping	Mean	Probability
Seed cotton yield kg ha^{-1}	1186	Cotton+soybean+pigeon pea intercropped cotton yield kg ha^{-1}	1340	0.000635
Net profitability Rs/Re investment	1.33	Net profitability	2.91	2.06E-10
Soybean yield kg ha^{-1}	2186	Soybea+pigeonpea stripcropping soybean yield kg ha^{-1}	1714	2.93E-06
Net profitability Rs/Re investment	3.07	Net profitability	1.57	1.68E-07

concluded that soybean + pigeon pea stripcropping is not economical due to 18 and 28% yield losses in shallow and medium deep soils, respectively.However, farmers grow on trial and error basis soybean : pigeon pea (4:1) in strips to meet their food legume requirement for domestic consumption, which acts as insurance incase of crop and price failures (Tables 5 and 6). There is no agronomical response for supplemental irrigations on sole vs strip cropping systems due to conservation of runoff in conservation furrows opened after strips. Micronutrients application did not respond with regular application of 5 t $ha^{-1}year^{-3}$ FYM and marginal yield levels of 1-1.5 t ha^{-1} when the soil content of Zn was in border line and B responded occassionally. However, verification of them in Bt hybrid cotton on farm trials for three years in Yeotmal district (M.S) found to improve 25 to 35% higher seed cotton yield when Zn, B along with two supplemental irrigations were applied (Raju and Thakare, 2012).

Pooled analysis of results found (Tables 7 and 13) $ZnSO_4$ 25 kg ha^{-1} $year^{-3}$, $MnSO_4$ 25 kg ha^{-1} $year^{-3}$, Borax 10 kg ha^{-1} $year^{-3}$ alone or together 2/3 rd soil application and 1/3 rd foliar application 3 times after square initiation with without 2% urea did not significantly improved the seed cotton yield, gross and net profitability in sole cotton planted as checkrow planting (2002 to 2004) similar tofarmer's practice or strip cropping with soybean and pigeon pea systems (Tables 7 and 13) of *G. hirsutum* hybrid cotton NHH 44 grown in shallow (<0.45 m) and medium deep soils (0.45 to 0.90 m) along with recommended dose of fertilizers 90:45:45 kg ha^{-1}N, P_2O_5:K_2O and organic manures F.Y.M at 5 t ha^{-1} $year^{-3}$ when soil available Zn(DTPA) was in border line, Mn in latent deficiency and B in deficient condition (Table 1 and Figure 3). This was due to sub-optimal seed cotton yields realized due to 4% lower plant stand than recommended plant population for sole cotton and 6.7% higher than recommended plant population was planted in stripcropping as followed by the farmers at border line of Zinc is not generating sufficient demand for micronutrients appication as its buildup was noticed in soil analysis (Table 1 and Figure 3).

However, significant improvement in yield for Zn, Mn, B soil application 2/3rd and 1/3 rd foliar application was observed only in 1/3 years, tha is, to the tune of 23% over control in 2002 to 2003 year with a normal onset of monsoon and slight deficit in July and excess in August month with more or less normal rainfall year. Present recommendation of integrated nutrient management package of chemical fertilizers 90:45:45 kg ha^{-1}N, P_2O_5:K_2O and organic manures F.Y.M at 5 t ha^{-1} $year^{-3}$ met the nutrient demand of moderate yields 1.2 to 1.5 tonn ha^{-1} besides improving the soil available Zn status 0.57 to 0.62 ppm after 6 years (Table 2). However, direct chemical application of $ZnSO_4$ 25 kg ha^{-1} $year^{-3}$ soil application benefitted only in years of better distribution or higher rainfall but built soil reserve was increased to 0.84 and 1.3 ppm at 20 and 40 cm depth compared to no change with foliar application (Table 1).

This was confirmed from the station and onfarm trials where regular annual application of farm yard manures in recommended level was practically impossible due to shortage of organic manures in Ralegaon Taluka of Yeotmal district (Maharashtra State), in Central India (Raju et al., 2011; Raju and Thakare, 2012). A regular application of F.Y.M at 5 t ha^{-1} $year^{-3}$ along with recommended fertilizers does not create a demand on a border line soil status for micronutrients application to cotton and soybean, stripcropping with pigeon pea with a moderate seed cotton yield level of 1.1 to 1.5 tonn ha^{-1} in shallow and medium deep soils. Micronutrient response was not observed in less rainfall years compared to wet monsoon years significant response was noticed in shallow rooted Bt hybrid cotton due to higher nutrient uptake with higher growth and better yield driven demand for micronutrients

Table 7. Agronomic performance of NHH 44 hybrid cotton in shallow soils.

Main plot treatment	Farmer's practice yield kg ha^{-1}		Cotton + Soybean + Pigeon pea inter strip cropping system yield kg ha^{-1}					Soybean+ Pigeon pea system yield kg ha^{-1}		Farmer's practice yield kg ha^{-1}	
	Cotton	NR/Re	Cotton	Pigeon pea	Soybean	CEY	NR/Re	Soybean	NR/Re	Soybean	NR/Re
Control	1095	0.86	792	387	1160	2216	1.29	1555	1.92	2044	2.73
$ZnSO_4$ 25 kg ha^{-1} year^{-3}	1029	0.78	943	435	1162	2069	1.38	1653	2.22	2249	2.56
$MnSO_4$ 25 kg ha^{-1} year^{-3}	1111	0.82	924	398	1122	2213	1.17	1299	1.97	2162	2.74
Borax 10 kg ha^{-1} year^{-3}	1175	1.01	965	463	1245	2154	1.28	1491	2.18	2361	2.57
Zn, $MnSO_4$ 25 Borax 10 kg ha^{-1} year^{-3}	1116	0.94	911	436	1240	2167	1.53	1424	2.01	2274	2.40
Zn, Mn, B foliar spray at 0.5 and 0.3%	1191	0.98	890	405	1132	2289	1.40	1604	2.30	2143	2.71
Zn, Mn, B foliar spray at 0.5 and 0.3% with 2% urea	1250	1.15	852	416	1071	2251	1.17	1465	2.11	2072	2.28
S.E.M. ± 5%	140	0.27	120	82	248	130	0.30	260	0.38	182	0.17
Rainfed cotton	1105	0.93	891	413	1131	2211	1.39	1555	2.06	2150	2.55
Supplemental irrigations(2)	1172	0.94	903	427	1193	2177	1.24	1443	2.15	2223	2.59
S.E.M. ± 5%	47	0.07	91	46	180	70	0.20	205	0.25	101	0.19
2005		0.93	946	454	1164	2095	1.18	1498	2.00	2275	3.60
2006			900	422	1126	2247	1.43	1474	2.13	2166	1.50
2007	1138		844	385	1195	2240	1.34	1523	2.17	2119	
S.E.M.CD ± 5%			55	45	45	173	0.06	57	0.15	55	0.99
			S	NS	NS	NS	NS	NS	NS	S	S
Season x Irrigation			NS	NS	NS	NS			NS		NS
S.E.M. ± 5%			157	80	312	226	0.3	356	0.43	176	0.57
Season x Micronutrient			NS	NS	NS	NS	NS	304	NS	263	0.98
S.E.M. ± 5%			136	78	274	226	0.32	NS	0.39	NS	NS
Irrigations x Micronutrients	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
S.E.M. ± 5%	188	0.28	208	119	477	184	0.49	465	0.28	263	1.28
S x I x M			NS	NS	NS	NS	NS	NS	NS	NS	NS
S.E.M. ± 5%			415	211	826	320	0.94	943	0.51	465	1.38

Zn, Mn and B application (Raju and Thakare, 2012).

Fibre quality

Shallow soils

Pooled analysis found $MnSO_4$ 25 kg ha^{-1} year^{-3}, Borax 10 kg ha^{-1} year^{-3} soil application or foliar spray at 0.5 and 0.3%, respectively 3 times after square initiation significantly improved the micronaire of the third pick cotton in 4 years trials of shallow soils by 3 to 4.6% (Table 8). However, in shallow soils 't' test indicated that micronaire 3rd picked cotton could be improved from discount range to premium quality with $MnSO_4$ 25 kg ha^{-1} year^{-3} and Borax 10 kg ha^{-1} year^{-3} soil application, respectively in rainfed and two supplemental irrigations (Table 11). Zn, Mn and B foliar spray at 0.5 and 0.3% twice from square initiation to flowering stage under supplemental irrigations also can produce similar effect (Tables 9 and 10). Similar to micronaire of 3rd pick cotton with two supplemental irrigations bundle strength g/tex of

Table 8. Fibre properties of NHH 44 hybrid cotton in shallow soils.

Treatment	Staple length mm		Uniformity ratio		Micronaire		Bundle strength g/tex	
Main plot treatment	**1st**	**3rd**	**1st**	**3rd**	**1st**	**3rd**	**1st**	**3rd**
Control	24.9	22.0	50.0	49.3	4.42	3.24	18.8	16.2
$ZnSO_4$ 25 kg ha^{-1} yr^{-3}	24.7	22.0	49.5	48.3	4.50	3.29	19.5	16.0
$MnSO_4$ 25 kg ha^{-1} yr^{-3}	25.0	21.9	50.6	49.6	4.43	3.35	19.4	16.0
Borax 10 kg ha^{-1} yr^{-3}	24.8	22.3	49.9	48.6	4.60	3.39	18.5	16.4
Zn, Mn SO_4 25 Borax 10 kg ha^{-1} yr^{-3}	24.4	21.8	49.6	49.1	4.44	3.34	19.3	16.0
Zn, Mn, B foliar spray at 0.5 and 0.3%	24.3	22.4	50.2	49.1	4.45	3.36	19.0	16.6
Zn, Mn, B foliar spray at 0.5 and 0.3% with 2% urea	24.5	22.2	50.4	49.3	4.41	3.24	19.1	16.7
S.E.M. ± 5%	0.5	0.4	0.4	0.7	0.10	0.17	0.4	0.4
CD ± 5%	0.9	0.9	0.8	1.6	0.21	0.34	0.8	0.8
	NS	NS	NS	NS	NS	S	NS	NS
Pure rainfed cotton	24.5	22.1	50.0	49.2	4.44	3.32	19.0	16.2
Two supplemental irrigations	24.9	22.1	50.0	48.9	4.49	3.31	19.2	16.3
S.E.M. ± 5%	0.3	0.3	0.3	0.3	0.04	0.30	0.3	0.1
CD ± 5%	0.9	0.6	0.6	0.6	0.08	0.11	0.6	0.3
	S	NS	NS	NS	NS	NS	NS	NS
2004	24.9	22.6	49.7	47.8	4.31	3.21	19.2	16.8
2005	24.4	21.8	50.1	49.5	4.68	3.47	19.1	16.2
2006	24.4	22.1	49.8	49.2	4.70	3.46	18.8	16.5
2007	25.0	21.8	50.4	49.5	4.17	3.13	19.1	15.7
SE ± 5%	3.5	0.2	0.4	0.3	0.08	0.07	0.3	0.2
CD ± 5%	0.4	0.5	0.7	0.6	0.16	0.13	0.5	0.4
	S	**S**	NS	S	S	S	NS	S
Micronutrients (M) x Irrigations (I)	0.5	0.7	0.9	0.9	0.21	0.17	0.7	0.6
CD ± 5%	1.0	1.3	1.7	1.8	0.42	0.34	1.4	1.2
M x S	0.5	0.7	0.9	0.9	0.20	0.18	2.6	0.6
CD ± 5%	1.0	1.5	1.9	1.9	0.39	0.36	0.7	1.1
Irrigations x Seasons	0.3	0.4	0.5	0.5	0.11	0.10	1.4	0.3
CD ± 5%	0.5	0.8	1.0	1.0	0.21	0.19	1.8	0.6
M x I x S	0.7	1.1	1.3	1.3	0.28	0.25	3.7	0.8
CD ± 5%	1.4	2.2	2.6	2.6	0.56	0.51		1.6

Medium deep soils

3rd pick cotton could be improved significantly with Zn, Mn and B foliar spray at 0.5 and 0.3% twice from square initiation to flowering stage in shallow soils (Table 12). Micronaire was abnormal in both pickings in 2004 and2007 due to drought in 2004 season (<49 mm) from September while it was six times higher in 2007(280 mm). Zn, Mn and B all of

Table 9. Micronaire of 3rd picked of cotton as influenced by different treatments during 2004 to 2006 in shallow soils.

Rainfed	Mean	Probability	Two supplemental irrigations	Mean	Probability
Control	3.37		Control	3.29	0.26
$ZnSO_4$ 25 kg ha^{-1} $year^{-3}$	3.40	0.37	$ZnSO_4$ 25 kg ha^{-1} $year^{-3}$	3.35	0.28
$MnSO_4$ 25 kg ha^{-1} $year^{-3}$	3.59	0.02*	$MnSO_4$ 25 kg ha^{-1} $year^{-3}$	3.28	0.47
Borax 10 kg ha^{-1} $year^{-3}$	3.50	0.17	Borax 10 kg ha^{-1} $year^{-3}$	3.60	0.01*
Zn, Mn SO_4 25 Borax 10 kg ha^{-1} $year^{-3}$	3.42	0.32	Zn, Mn SO_4 25 Borax 10 kg ha^{-1} $year^{-3}$	3.38	0.20
Zn, Mn, B foliar spray at 0.5 and 0.3%	3.42	0.32	Non chelated micronutrients spray	3.61	0.01*
Zn, Mn, B foliar spray at 0.5 and 0.3% with 2% urea	3.47	0.20	Chelated micronutrients spray	3.30	0.46
Mean	3.46		Mean	3.40	0.10

Table 10. Bundle strength g/tex of 3rd picked as influenced by different treatments during 2004 to 2006 in shallow soils.

Rainfed	Mean	Probability	Supplemental irrigations	Mean	Probability
Control	16.7		Control	17.2	0.17
$ZnSO_4$ 25 kg ha^{-1} $year^{-3}$	16.3	0.58	$ZnSO_4$ 25 kg ha^{-1} $year^{-3}$	17.1	0.44
$MnSO_4$ 25 kg ha^{-1} $year^{-3}$	16.9	0.33	$MnSO_4$ 25 kg ha^{-1} $year^{-3}$	16.9	0.35
Borax 10 kg ha^{-1} $year^{-3}$	16.7	0.42	Borax 10 kg ha^{-1} $year^{-3}$	16.7	0.19
Zn, Mn SO_4 25 Borax 10 kg ha^{-1} $year^{-3}$	17.0	0.28	Zn, Mn SO_4 25 Borax 10 kg ha^{-1} $year^{-3}$	16.6	0.21
Zn, Mn, B foliar spray at 0.5 and 0.3%	17.7	0.02	Non chelated micronutrients spray	16.4	0.14
Zn, Mn, B foliar spray at 0.5 and 0.3% with 2% urea	17.3	0.17	Chelated micronutrients spray	17.0	0.36
Mean	16.7		Mean	16.8	0.29

Table 11. Micronaire of 3rd picked cotton as influenced by different treatments during 2004 to 2007 in medium soils.

Rainfed	Mean	Probability	Supplemental irrigations	Mean	Probability
Control	3.23		Control	3.22	
$ZnSO_4$ 25 kg ha^{-1} $year^{-3}$	3.2	0.42	$ZnSO_4$ 25 kg ha^{-1} $year^{-3}$	3.10	0.14
$MnSO_4$ 25 kg ha^{-1} $year^{-3}$	3.13	0.11	$MnSO_4$ 25 kg ha^{-1} $year^{-3}$	3.25	0.42
Borax 10 kg ha^{-1} $year^{-3}$	3.23	0.33	Borax 10 kg ha^{-1} $year^{-3}$	3.26	0.38
Zn, Mn SO_4 25 Borax 10 kg ha^{-1} $year^{-3}$	3.31	0.47	Zn, Mn SO4 25 Borax 10 kg ha^{-1} $year^{-3}$	3.28	0.34
Zn, Mn, B foliar spray at 0.5 and 0.3%	3.22	0.29	Non chelated micronutrients spray	3.26	0.39
Zn, Mn, B foliar spray at 0.5 and 0.3% with 2% urea	3.22	0.30	Chelated micronutrients spray	3.20	0.42
Mean	3.22			3.23	0.44

them together soil application 66% and 33% foliar application or Zn, Mn and B foliar spray at 0.5 and 0.3%, respectively twice after square initiation brought significantly improved the micronaire of the 3rd pick cotton in medium deep soils from discount range to premium quality. Micronaire of 3rd pick cotton was significantly interacted with Irrigation and micronutrients besides strength with season (Tables 14 and 15). Soil application of micronutrient Mn SO_4 25 kg ha^{-1} $year^{-3}$, Borax 10 kg ha^{-1} $year^{-3}$ with two supplemental irrigations and Zn, Mn and B foliar spray at 0.5 and 0.3%, respectively under rainfed conditions significantly improved last pick cotton

Table 12. Bundle strength g/ tex of 3rd picking as influenced by different treatments during 2004 to 2007 in medium soils.

Rainfed	Mean	Probability	Supplemental irrigations	Mean	Probability
Control	15.9		Control	15.61	0.28
$ZnSO_4$ 25 kg ha^{-1} year^{-3}	15.62	0.27	$ZnSO_4$ 25 kg ha^{-1} year^{-3}	15.62	0.49
$MnSO_4$ 25 kg ha^{-1} year^{-3}	15.74	0.33	$MnSO_4$ 25 kg ha^{-1} year^{-3}	16.18	0.17
Borax 10 kg ha^{-1} year^{-3}	15.36	0.13	Borax 10 kg ha^{-1} year^{-3}	15.83	0.36
Zn, Mn SO_4 25 Borax 10 kg ha^{-1} year^{-3}	15.73	0.34	Zn, Mn SO_4 25 Borax 10 kg ha^{-1} year^{-3}	16.09	0.16
Zn, Mn, B foliar spray at 0.5 and 0.3%	15.96	0.44	Non chelated micronutrients spray	15.47	0.39
Zn, Mn, B foliar spray at 0.5 and 0.3% with 2% urea	16.16	0.29	Chelated micronutrients spray	16.12	0.22
Mean	15.78		Mean	15.91	0.23

Table 13. Agro economics of hybrid cotton inter/strip cropping in medium deep soils.

Main plot treatment	Cotton yield (kg ha^{-1})	NR/Re	CSPP inter crop yield (kg ha^{-1})			Net return Re investment Rs.		CEY (kg ha^{-1})		Soybean yield (kg ha^{-1})		
Micronutrient			Cotton	Ppea	SPP	SPP	CSPP			SPP	Pure	Net Re/R
Control	1256	1.41	1315	491	1776	1.55	2.83	2216		1618	2044	3.23
$ZnSO_4$ 25 kg ha^{-1} year^{-3}	1197	1.37	1205	465	1799	1.46	2.80	2069		1531	2249	3.18
$MnSO_4$ 25 kg ha^{-1} year^{-3}	1183	1.26	1339	412	1770	1.51	2.87	2213		1636	2162	3.26
Borax 10 kg ha^{-1} year^{-3}	1202	1.27	1364	430	1733	1.62	2.84	2154		1804	2361	3.08
Zn, Mn SO_4 25 Borax 10 kg ha^{-1} year^{-3}	1153	1.41	1303	387	1461	1.65	2.90	2167		1607	2274	3.11
Zn, Mn, B foliar spray at 0.5 and 0.3%	1143	1.34	1393	377	1696	1.64	3.01	2289		1654	2143	2.66
Zn, Mn, B foliar spray at 0.5 and 0.3% with 2% urea	1169	1.25	1461	318	1766	1.54	3.17	2251		1697	2072	3.00
S.E.M. ± 5%	19	0.19	151	S	213	0.20	0.32	130	186	182		0.47
CD ± %	NS	NS	NS	92	NS	NS	NS	NS	NS	NS		NS
			Sub plot treatments: Irrigations (I)									
Rainfed cotton	1153	1.27	1354	403	1656	1.51	2.88	2177	1617	2223		3.25
Two supplemental irrigations	1220	1.39	1326	420	1773	1.63	2.95	2211	1682	2150		2.90
S.E.M. ± 5%	54	0.11	47	23	111	0.12	0.12	70	105	101		0.29
CD±5%	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS		S
			Sub –sub plot treatment: Seasons (S)									
2002/05	1395	1.56	1381	404	1649	1.30	2.58	2095	1615	2275		4.15
2003/06	1142	1.30	1282	430	1857	1.64	3.13	2247	1658	2166		1.72
2004/07	1022	1.14	1358	400	1637	1.77	3.03	2240	1675	2119		3.34
S.E.M. ± 5%	130	0.13	104	15	171	S	0.25	173	88	55		0.44

Table 13. Contd.

CD ± 5%	NS	NS	NS	NS	NS	0.21	NS	NS	NS	S	S
S x M	119	0.11	163	82	385	0.42	0.44	NS	366		NS
S.E.M. ± 5%	S	NS	S	S	S	S	S	226	S	176	0.25
S x I	NS	NS	231	NS	NS	NS	NS	NS	NS	263	NS
S.E.M. ± 5%	67	013	S	42	195	0.20	0.26	226	178	NS	0.29
I x M	NS	0.35	NS	NS	NS	NS	NS	NS	NS	NS	NS
S.E.M. ± 5%	91	S	125	63	294	0.30	0.34	184	272	263	0.59
S x I x M	316	0.35	432	217	1019	1.07	0.59	NS	NS	NS	NS
S.E.M. ± 5%	S	S	S	S	S	S	S	320	570	465	0.78

Table 14. Fibre properties of NHH 44 cotton in medium deep soils.

Fibre property	**2.5% staple length mm**		**Uniformity ratio**		**Micronaire**		**Strength g/tex**	
Picking	**1st**	**3rd**	**1st**	**3rd**	**1st**	**3rd**	**1st**	**3rd**
Main plots: Micronutrients								
Control	23	22	49.9	49.2	4.54	3.30	18.5	16.3
Zn 3 kg ha year	23.1	21.9	49.9	48.5	4.60	3.12	19.2	15.4
Mn 3 kg ha year	23.4	22.1	50.5	49.9	4.39	3.20	19.5	16.0
B 1 kg ha year	23.3	21.8	50.0	49.6	4.52	3.27	19.3	16.0
All	23.1	21.6	50.3	49.0	4.57	3.45	19.0	16.1
Zn, Mn, B foliar spray at 0.5 and 0.3%	22.9	21.8	50.3	49.1	4.46	3.35	19.9	16.3
Zn, Mn, B foliar spray at 0.5 and 0.3% with 2% urea	23	22.2	50.5	48.9	4.39	3.18	19.5	16.7
F test	NS	NS	NS	NS	S	S	NS	NS
SE/CD 5%	0.27	0.3	0.4	0.5	0.27	0.22	0.6	0.5
Sub plots irrigation								
Rainfed	23.1	21.9	50.2	49.4	4.4	3.3	19.3	16.1
Two supplemental Irrigations	23.2	21.9	50.2	49.0	4.5	3.4	19.4	16.1
F test	NS	NS	NS	NS	NS	NS	NS	NS
SE/CD 5%	0.16	0.14	0.3	0.2	0.04	0.04	0.3	0.1
Season								
2003	23.0	22.1	50.4	49	4.6	3.3	19.1	16.2
2004	23.2		50.6		4.5		19.3	
2005	23.2	22.1	49.9	49.6	4.4	3.4	19.1	16.3
2006	23.2	21.7	50.0	48.5	4.3	3.3	19.6	15.7

Table 14. Contd.

2007	23.0	21.0	50.1	49.6	4.4	3.3	19.3	16.1
F test	NS	NS	S	S	NS	NS	NS	NS
SE/CD 5%	0.16	0.16	0.51	0.7	0.8	0.1	0.5	0.3
Interaction								
S x I F test	S	S	NS	NS	NS	NS	NS	NS
SE/CD 5%	1.2	1.1	0.9	1.1	0.2	0.1	1.4	1.0
S x M F test	S	S	S	NS	S	S	NS	S
SE/CD 5%	1.2	1.1	0.94	1.0	0.3	0.3	1.4	2.0
I x M F test	NS	NS	NS	S	NS	S	NS	NS
SE/CD 5%	0.38	0.4	0.60	1.1	0.1	0.2	0.9	0.7
S x I x M F test	S	S	S	NS	S	S	S	S
SE/CD 5%	1.69	1.6	2.47	1.5	0.5	0.4	3.9	2.6

Table 15. Interaction of supplemental irrigations and micronutrients on micronaire of third pick cotton in medium soils.

Treatment	Supplemental irrigations	Rainfed
Control	3.37	3.25
Zn 3 kg ha year	3.26	3.39
Mn 3 kg ha year	3.40	3.24
B 1 kg ha year	3.45	3.23
All micronutrients	3.34	3.18
Zn, Mn and B foliar spray at 0.5 and 0.3%	3.27	3.42
Zn, Mn and B foliar spray at 0.5 and 0.3% with 2% urea	3.38	3.21
CD ± 5%		0.2

micronaire to premium range.

Supplemental irrigations

Yield and profitability: Two supplemental irrigations in the beginning of winter season in early October month from the harvested rainwater in farm ponds did not significantly improved the seed cotton yields or profitability in both shallow and medium soils in a six years experimentation period, it does not justify investments on farm ponds to create supplemental irrigations to deep rooted drought resistant either pure or strip cropped cotton/soybean (Tables 7 and 13). Rainfall distribution during July to October months of six years period followed more or less normal pattern (Figure 1). Therefore, there is no significant response or improved profitability of pure cotton 2002 to 2004 and rainwater conserved by stripcropping during 2005 to 2007 years (Singh et al., 2008).

Conclusion

Shallow soils were most profitable for sole soybean cultivation only in assured rainfall areas.

Strip cropping of cotton + soybean + pigeon pea d(4:4:2) is most profitable under rainfed conditions by 47 and 58% over sole cotton in shallow and medium deep soils, respectively. Micronaire of last picked cotton could be improved under rainfed conditions in coarse textured shallow soils with Mn SO_4 25 kg ha^{-1} $year^{-3}$ soil application or Zn, Mn and B at 0.5 and 0.3% foliar spray twice in medium deep soils. Two supplemental irrigations after cessation of monsoon can be benefitted with Borax 10 kg ha^{-1} $year^{-3}$ soil application in shallow soils or Zn, Mn and B at 0.5 and 0.3% foliar spray twice after square initiation in medium deep soils brought significant improvement in micronaire and kept the fibre discount to premium range.

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Full length Research paper

Effect of sowing dates and seed rates on some rice cultivars

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Two field experiment were conducted at Rice Research and Training Center (RRTC) – Sakha, kafr- El sheikh, governorate, Egypt in 2006 and 2007 seasons., to study the effect of seed rates under different of sowing dates (20th April, 1st May and 10th May) on some rice varieties. Three rice varieties Sakha 101, Sakha 103, Sakha 104 were tested. Three seed rates were used (48, 95 and 144 kg /ha). Nitrogen fertilizer was added as urea form 46.5% N in two splits, 2/3 was applied as mixed in dry soil before flooding irrigation water and 1/3 was added at panicle initiation. Under three different sowing dates 20th April, 1st May and 10th May with seedling age were transplanted 25 days from sowing by 20×20 cm planting spacing. All agricultural practices were added as recommended for each cultivar. The study was arranged as split- split plot design and with four replications; three sowing dates were allocated in the main plots; seeding rates were allocated in sup-plots and three rice varieties were allocated in the sup-sup plots. The results found that maximum tillering, panicle initiation, heading dates, leaf area index, chlorophyll content, 1000-grain weight, panicles length, number of panicles per hill and grain yield (Ton/ha^{-1}) were increase by increased seed rates up to 143 kg seed ha^{-1}. Earlier sowing time (20th April) date of sowing gave had the highest value of all studied characters in Sakha 101 variety and this rice variety surpassed other varieties to all attributes under study. While 30th May date of sowing with Sakha 103 inbred rice gave the lowest value of all traits under study.

Key words: Normal soil, rice crop, sowing dates, seed rates, rice varieties, physiological characters, yield.

INTRODUCTION

Rice crop is a main crop among different cultivated crops under Egyptian condition and all over the world. The experiment were conducted to study the effect of seed rates under different of sowing dates (20th April, 1st May and 10th May) on some rice varieties. Rice hybrids have a mean yield advantage of 10 to 15% over traditional varieties higher growth and development processes associated with higher grain yields of rice hybrids include a more vigorous and extensive root system (Li, 1981; Yang and Sun, 1989), increased growth rate during vegetative growth (Yamauchi, 1994), more efficient sink formation and greater sink size (Kabaki, 1993), greater carbohydrate translocation from vegetative plant parts to the spikelets (Song et al., 1990), and larger leaf area index (LAI) during the grain-filling period, but the physiological basis for heterosis remains unknown (Peng, 1998).

El-Hity et al. (1987) found that number of days after sowing (D.A.S) up to panicle initiation (P.I), maximum tillering (M.T.), heading dates (H.D.) and grain yield (t/ha^{-1}) were drastically reduced with delay of sowing. Abou Khalifa (1996) found that plant height, number of tillers/m^{-2}, and crop growth rate at 75 to 90 and 90 to 105 D.A.S were significant decreased by sowing delay from May 25th to June 15th. Sharief et al. (2000) found that early sowing dates (May 10 th) had marked effect on number of

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Table 1. Soil chemical analysis of the experimental slits.

Soil characters	2006	2007	Mean
pH	7.3	7.4	7.35
EC	1.4	1.5	1.45
Organic matter (%)	2.1	2.4	2.25
Total N (%)	0.32	0.39	0.36
Available P (ppm)	17.55	19.20	18.38
Available K (ppm)	685.0	675.0	680
Available Zn (ppm)	1.4	1.3	1.35
Total soluble salts (mg/L)	10	14.0	12

panicles /m^{-2}, number of filled grains / per panicle, 1000-grain weight, grain and straw yields/fed^{-1}. El-Khoby (2004) showed that delaying sowing date sharply decreased the leaf area index, dry matter production and chlorophyll content. In addition, delaying sowing date up to June 15th significantly reduced (D.A.S) to heading. Abou Khalifa (2005) found that number of days from sowing up to maximum tillering, panicle initiation and heading date was significant affected by different sowing dates. Whereas, D. A. S. was higher under early sowing (April 20th) and gradually decreased with delaying sowing up to May 20th .Seeding rates is important traits for achieving higher seed yield in rice (Kurmi and Sarmah, 1993). Abou Khalifa et al. (2005) found that 1000-grain weight (g), number of grain/ per panicle and grain yield t/ha^{-1} were increased by increase seeding rate to 50 kg /fed^{-2} (Cock and Yoshida, 1972). Shortage of assimilate supply due to inhibition of photosynthetic processes is one of the major factors determining grain filling. Hari et al. (1997) and Rajendran and Veeraputhirm (1999) reported that low seed rate, 10 or 20 g/m^{-2} resulted high seedling quality, proper shoot dry weight and leaf area /per plant. Rieffel et al. (2000) found that both conventional and hybrid rice have differently responded to seed rates (Hoshikawa, 1967; Egli, 1998). From previous studies, however, it is doubtful that assimilate supply to the grain during the early grain filling period alone defines potential grain growth and determines final grain weight. If assimilate supply to rice is restricted by shading or unfavorable cultivated conditions in the first 10 days of the grain filling period, the grain may be profoundly affected, as grain growth rate is generally highest within the 2 week after heading. El-Khoby (2004) found significant variations among rice cultivars in growth, yield attributes and grain yield. El-kallawy (2002) studied the effect of different seeding rates, form 30 to 80 kg seed/fed on seedlings vigor. He found that low seed rate has significantly raised the seedling vigor where it gave the highest values of leaf area /plant^{-1} and leaf number /per stem, Abou Khalifa et al. (2005) showed that the optimum seed rate was 114 kg seed /ha^{-1}.

The study aims to find the optimum sowing date and best seeding rate with all cultivars under study.

MATERIALS AND METHODS

A field experiment was conducted at Rice Research and Training Center (Sakha—Kafr El Sheikh, Egypt) in 2006 and 2007 seasons to study the response of 4 rice varieties for seeding rates under different dates of sowing. Three rice varieties (Sakha 101, Sakha 104 and Sakha 103) were used in this study. Three seeding rates were used (48, 95 and 144 kg seed/ha^{-1}). Three sowing dates were investigated at 20th April, 1st May and 10th May with seedling age 25 days were transplanted in hills spaced 20×20 cm for in 3×5 m plots. As split-split plot design with four replications was used. Sowing dates were allocated to the main plots, seeding rates in the sup-plot while rice varieties in the sup-sup plot. Nitrogen fertilizer was applied as urea form 46.5% N in two splits; 2/3 was application mixed in dry soil before flooding irrigation water and 1/3 was added at panicle initiation at stage of each rice variety).

Irrigation was carried out at usual local quantities, that is, 12000 m^2/ha. Such quantity was controlled by the use of partial flew (cut throw flew).

Soil sample from the experimental sites were collected from 0 to 30 cm depth. Sub sample were taken to the laboratory for chemical analysis according to Black et al. (1965). The results of analysis are presented in Table 1.

Studied topics and traits

1. Growth attributors: Data were recorded as DAS up to 50% heading. The following three traits were studied:

a. Light penetration by Lux / meter Pu 150 k – Pu,
b. Leaf area index by leaf area meter Minolta Camera Co. Ltd.,
c. Total chlorophyll content in the leaves of plants were recorded using chlorophyll meter 5 SPAD-502 Minolta Camera Co. Ltd., Japan (Futuhara et al., 1979) at heading date.

2. Yield attributes and yield:

a. No. of panicles/m^2, at 60 DAS the determination of panicles was daily recorded,
b. No. of grains/ panicle,
c. Panicle length (cm),
d. The 1000-grain weight (g),
e. No. of spikelets /m^2 (1000),
f. Spikelets – leaf area ratio,
g. Grain yield (ton/ha),
h. Straw yield (ton/ha). Both grain yield and straw yield were estimated from 12 m^2 (3×4 m) in the center of sub-sub plots. Grain yield was adjusted to 14% moisture content according to Yoshida (1981),

Table 2. Light penetration, leaf area index and chlorophyll content as affected by sowing dates, seeding rates and rice cultivars in the two studied seasons.

Treatments	Chlorophyll content (ppm)		Leaf area index (cm)		Light penetration (Lux)	
	2006	2007	2006	2007	2006	2007
Sowing dates						
April 20th	36.75	32.19	6.49	6.28	1906	1856
May 1st	31.83	26.33	6.36	6.04	2034	1984
May 10th	29.75	25.19	5.86	5.77	2164	2151
LSD $_{P<0.05}$	3.59	3.76	0.33	0.26	129	148
Seeding rates (kg ha^{-1})						
48 kg ha^{-1}	31.17	25.67	5.91	5.75	3650	3611
95 kg ha^{-1}	32.22	27.67	6.39	6.13	1541	1517
144 kg ha^{-1}	33.23	29.24	6.41	6.22	913	863
LSD $_{P<0.05}$	1.03	1.79	0.29	0.22	1433	1435
Cultivars						
Sakha 101	38.19	31.61	6.87	6.60	1986	1973
Sakha 104	32.94	27.47	5.98	5.77	2008	1958
Sakha 103	27.19	24.64	5.86	5.72	2111	2061
LSD $_{P<0.05}$	5.50	3.51	0.55	0.50	66	55

9. Harvest index (grain yield / straw yield).

The present study was planned to test the performance of some newly rice cultivars, under some dates and seeding rates, under an almost region, when flood irrigation is prevailing, for producing rice in Egypt. The final goal was to recommend a superior combination treatment for producing pronounced rice yield per unit area. Data collected were subjected to statistical analysis of variance according to Gomez and Gomez (1984) using IRRISTAT computer program. LSD test was used for comparing mean.

RESULTS AND DISCUSSION

Data in Table 2 showed that April 20th gave the highest value of leaf area index, and chlorophyll content, oppress light penetration was decreased at 20th April date of sowing. Leaf area index and chlorophyll content were increased by increasing seeding rates to 144 kg seed / ha ha^{-1}. On the other hand, light penetration was decreased by increasing seeding rates to (144 seed / ha ha^{-1}). Sakha 101 gave the highest value to leaf area index and chlorophyll content while light penetration was decreased at Sakha 103 rice Varity these data are in agreement with those reported by Song et al. (1990), El-Khoby (2004) and Abou Khalifa (2005).

Data in Table 3 showed that all aspects were obtained on April 20th. While May 10th gave the lowest value of number of panicles /m^2, 1000-grain weight, panicle length (cm). On the other hand number of panicles/m^2, 1000-grain weight, panicle length (cm) were increased by increasing seeding rates to (144 kg /ha). Sakha 101 rice variety surpassed other varieties as to respects all trails. The brews data are in a good harmony with those reported by Sharief et al. (2000) and Abou Khalifa et al. (2005)

Data in Table 4 gave means of number of spikelets/m^2 (1000), spikelets-leaf area ratio and number of grains/ panicle as affected by sowing dates, seeding rates, and rice cultivars in the two studied seasons. Number of spikelets/m^2*1000, spikelets-leaf area ratio and number of grains/panicle were decreased by delays in Agriculture to May 10th date of sowing, while all previous attribute were increased by increase seeding rates to 144 kg/ha.

However Sakha 101 gave the highest value of number of spikelets/m^2*1000, spikelets-leaf area ratio and number of grains/ panicle. While Sakha 103 rice varieties gave the lowest value to all previous attribute. These results are in agreement with those reported by Abou Khalifa et al. (2005), Song et al. (1990) and El-Khoby (2004).

Table 5 Indicates April 20th sowing date gave the highest value of grain yield (T/ha), straw yield (T/ha) and harvest index, while May 10th gave the lowest value of all previous attribute. Grain yield (T/ha), straw yield (T/ha) and harvest index were increased by increase seeding rates to (144 kg /ha). On the other hand Sakha 101 surpassed other varieties under study to all previous attribute. The brews data are in a good harmony with those reported by Abou Khalifa et al. (2005), Song et al. (1990) and El-Khoby (2004). Figure 1A showed that higher Leaf area ratio was obtained from the interaction between 197 kg/ha seeding rate under 20th April date of

Table 3. Number of panicles /m^2, 1000-grain weight and panicle length (cm) as affected by sowing dates, seeding rates and rice cultivars in the two studied seasons.

Treatments	No. of panicles/m^2		1000-grain weight		Panicle length (cm)	
	2006	2007	2006	2007	2006	2007
Sowing dates						
April 20th	425	408	23.75	22.75	24.56	24.28
May 1st	391	408	23.58	23.33	24.36	24.03
May 10th	344	348	23.24	23.34	24.16	23.85
LSD $_{P<0.05}$	41	35	0.26	0.34	0.20	0.22
Seeding rates (kg ha^{-1})						
48 kg	344	347	23.92	23.11	24.19	23.70
95 kg	373	361	23.45	23.22	24.38	24.08
144 kg	441	456	23.19	23.09	24.51	24.38
LSD $_{P<0.05}$	50	26	0.37	0.07	0.16	0.34
Cultivars						
Sakha 101	457	454	24.88	24.44	24.44	24.64
Sakha 104	364	357	24.37	22.74	22.74	23.78
Sakha 103	338	352	21.31	22.25	22.25	23.74
LSD $_{P<0.05}$	63	58	1.93	1.15	1.15	0.51

Table 4. Number of panicles /m^2, 1000-grain weight and panicle length (cm) as affected by sowing dates, seeding rates, and rice cultivars in the two studied seasons.

Treatments	No. of spikelets /M^2*1000		Spikelets-leaf area ratio		Number of grains/ panicle	
	2006	2007	2006	2007	2006	2007
Sowing dates						
April 20th	78	72	12.04	11.53	184	179
May 1st	68	68	10.69	11.23	174	168
May 10th	53	51	9.04	8.78	154	147
LSD $_{P<0.05}$	12	11	1.50	1.78	14.90	16.13
Seeding rates (kg ha^{-1})						
48	58	55	9.73	9.47	166	160
95	63	58	9.82	9.48	168	163
144	79	78	12.22	12.60	177	171
LSD $_{P<0.05}$	11	13	1.42	1.81	5.72	5.69
Cultivars						
Sakha 101	80	73	11.57	11.09	174	168
Sakha 104	61	59	10.15	10.31	166	161
Sakha 103	58	58	9.87	10.14	171	165
LSD $_{P<0.05}$	12	8	0.91	0.51	3.89	3.64

sowing, while 95 kg/ha seeding rate with 10th May gave the lowest value of leaf area ratio. Figure 1B showed that the interaction between 197 kg/ha seeding rate with Sakha 101 gave the highest value of leaf area ratio, while 95 kg/ha seeding rate with Sakha 103 gave the lowest value of leaf area ratio (Hoshikawa, 1967; Egli, 1998).

Figure 2A showed that higher leaf area index and grain yield was obtained from 20th April date of sowing on the other hand 10th May gave the highest value of light penetration. Figure 2B showed that Sakha 101 surpassed

Table 5. Grain yield (T/ha), straw yield (T/ha) and harvest index as affected by sowing dates, seeding rates and rice cultivars in the two studied seasons.

Treatments	Harvest index		Straw yield(T/ha)		Grain yield(T/ha)	
	2006	2007	2006	2007	2006	2007
Sowing dates						
April 20th	0.46	0.47	21.89	20.28	10.04	9.35
May 1st	0.43	0.46	21.56	19.56	9.10	8.80
May 10th	0.33	0.43	20.76	18.66	6.10	8.06
LSD $_{P<0.05}$	0.07	0.02	0.58	0.81	2.06	0.65
Seeding rates (kg ha^{-1})						
48 kg ha^{-1}	0.34	0.40	18.09	16.31	7.05	8.22
95 kg ha^{-1}	0.43	0.46	22.30	20.30	8.23	8.77
144 kg ha^{-1}	0.46	0.50	23.82	21.90	9.97	9.23
LSD $_{P<0.05}$	0.06	0.05	2.97	2.88	1.47	0.50
Cultivars						
Sakha 101	0.46	0.51	20.64	18.63	9.45	0.51
Sakha 104	0.36	0.39	22.17	20.32	7.51	0.39
Sakha 103	0.41	0.46	21.41	19.56	8.28	0.46
LSD $_{P<0.05}$	0.05	0.06	0.77	0.85	0.98	0.06

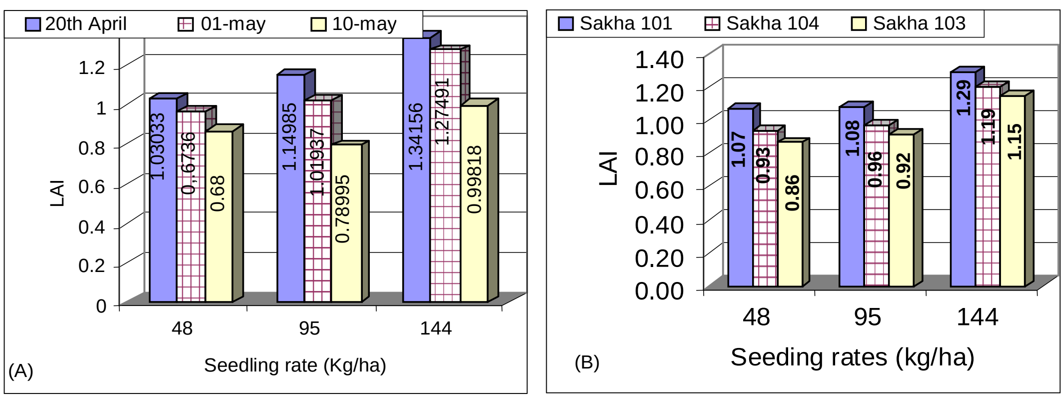

Figure 1. Effect of the interaction between seeding rates with (A) sowing dates and (A) rice varieties on Leaf area ratio.

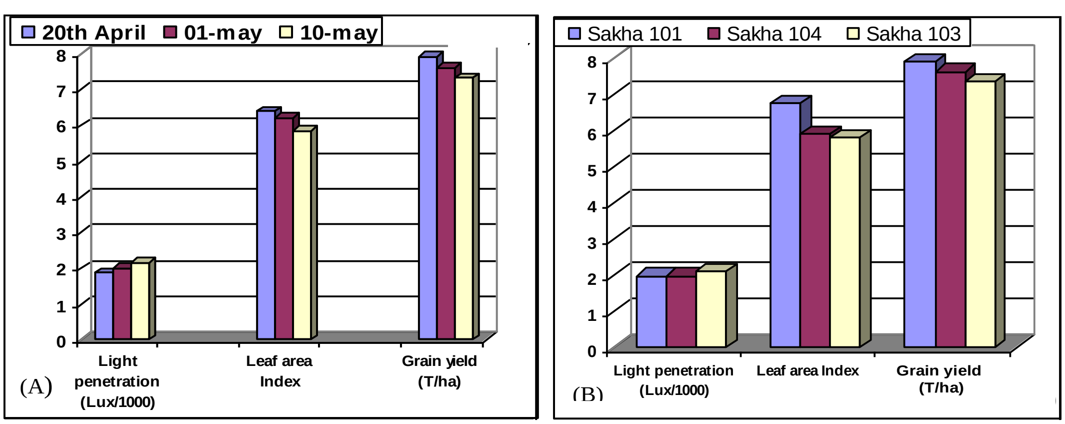

Figure 2. Light penetration, leaf area index and grain yield (T/ha) as affected by sowing dates and some rice varieties.

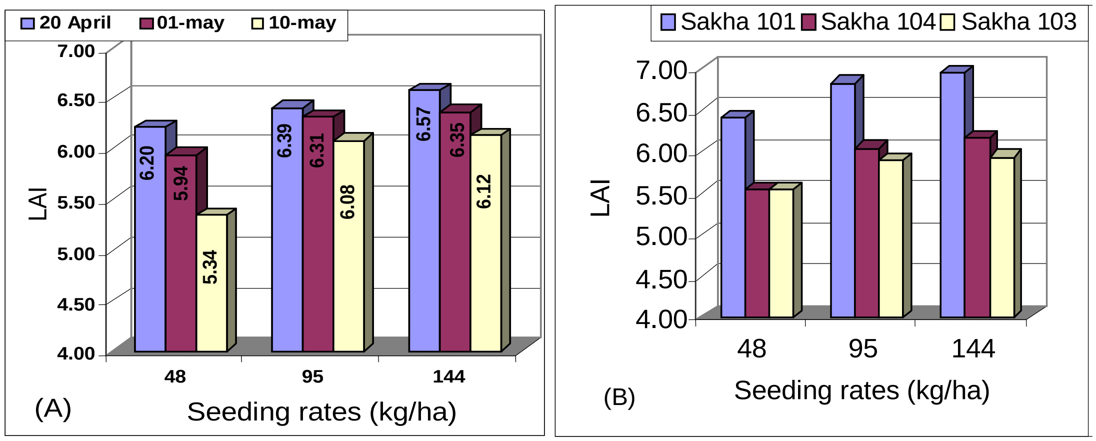

Figure 3. Effect of the interaction between sowing dates, seeding rates with rice varieties on leaf area index.

other varieties under study of leaf area index and grain yield (T/ha). Higher light penetration was obtained from Sakha 103 rice variety. These data are in agreement with those reported by Hoshikawa (1967) and Egli (1998).

Data in Figure 3 recorded that the interaction between 144 kg/ha seeding rate under 20th April dates of sowing condition gave the highest value of leaf area index. While the interaction between 48 kg /ha seeding rate with 10th May date of sowing gave the lowest value of leaf area index. Figure 3B showed that the interaction between Sakha 101 with 144 kg /ha seed rate gave the highest value of leaf area index. The brews data are in a good harmony with those reported by Hoshikawa (1967) and Egli (1998).

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Full Length Research Paper

Adoption behaviour of potato growers in sub-tropical zone of Jammu division

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The study on extent of adoption of recommended irrigation schedule and intercultural practices in potato crop by farmers in sub-tropical zone of Jammu division was conducted during 2011 to 2012. Three districts namely Jammu, Kathua and Samba were selected purposively on the basis of maximum area under potato crop. These are the main potato growing districts in Jammu division. A sample size of 225 potato growers was selected randomly from 15 villages and from each village 15 potato growers were selected randomly. The findings revealed that 31.5% of respondents had adopted recommended irrigation practices 5-6 numbers and 49.3% adopted right time of irrigation as per recommendation. Similarly, cent percent had applied furrow method of irrigation. In case of intercultural practices like hoeing and earthing-up of potato 41.33 and 58.4% of respondents adopted these practices, respectively. The study further indicated that a majority of potato growers (67%) had adopted manual weed control measures and only 16% adopted dehaulming practice in potato.

Key words: Adoption behaviour, potato, irrigation and intercultural practices.

INTRODUCTION

Potato (*Solanum tuberosum* L.) is one of the major tuber crop of the world. It is a wholesome food and consumed by all sections of the people. It is also becoming an important source of rural employment and income for growing population (Hort, 1987). It produces 74.5 and 58.0% more food energy and 54.0 and 77.6% more protein per unit area than wheat and rice respectively (Lisinska and Leszezynski, 1989). India produced 42.34 million tons from 1.86 million ha with an average yield of 22.72 tons/ ha of potato during 2010 to 2011 (Agricultural statistics at a glance, 2012). India is the second largest producer of potato in the world after China and both the countries put together contribute nearly one third of the global potato production (Scott and Suarez, 2012). India in particular and Asia in general are showing rapid growth in potato production. Potato is highly remunerative crop of Jammu and Kashmir, particularly in high altitude and cold arid areas. In Jammu division, it is a leading cash crop and has highest area cover after rice, wheat and maize, sharing 16% in area and 18% in production under

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Table 1. Selection of the districts, sub-divisions, area, villages and respondents.

District	Sub division	Area under potato crop (ha)	Number of potato growing villages	Number of villages selected by proportionate sampling method (proportionate to area)	Number of potato growers were selected by random sampling method
Jammu	Marh	1100	16	7	105
	R S Pura	700	11	4	60
Kathua	Dayalachak	450	7	3	45
Samba	Samba	85	8	1	15

Source: Anonymous (2010).

vegetables. During last five years, there has been 10% increase in areas from 4845 ha in 2002 to 2003 to 5650 ha in 2008 to 2009. Similarly, the production has shot up by 9% during the same period from 75485 to 89600 MT with overall average productivity of 15.3 to 16.0 MT/ha (Anonymous, 2010). Still, there is deficiency of this tuber crop to cater for the high population pressure.

The present paper reports the situation with regard to extent of adoption of important crop practices like irrigation and intercultural practices recommended by Concerned SAU for the crop. This survey was needed to have an insight over the prospects of productivity improvement and to sought out problems faced by the growers in the subtropical area of Jammu.

MATERIALS AND METHODS

On the basis of proportionality of area under potato cultivation, three districts namely Jammu, Kathua and Samba of the Jammu division were selected. Under each district, sub-divisions like Marh and R S Pura of Jammu district, Dayalachak of Kathua district and Samba of Samba district were selected. Among each sub-divisions, seven villages from sub-division Marh, four villages from sub-division R S Pura, three villages from sub-division Dayalachak and one village from sub-division Samba were selected. From each village, 15 respondents were selected randomly, making a total sample size of 225 farmers (Table 1). In this study, adoption was studied under extent and level of adoption of recommended crop production technologies by the potato growers in the sub-tropical zone of Jammu division. The recommendations of irrigation schedule and intercultural practices of Sher-e-Kashir University of Agricultural Sciences and Technology of Jammu (SKUAST-J) were selected for the study. Extent of adoption was measured with respect to percentage of farmers adopting a recommended practice and level of adoption was measured in case of divisible practices namely, dosage of pesticides (Singh and Peshin, 2000).

The interview schedule was administered to collect data and analyzed through simple frequency and percentage on multiple responses. The findings are presented as per the expressed responses of the respondents.

Scoring pattern for the adoption of recommended crop production technologies

Technologies adopted as per recommendation by the growers were assigned a score of 2. The deviation from the recommendation whether on the higher or lower side were assigned a score of 1. Non- adopters of practices were assigned a score of 0.

RESULTS AND DISCUSSION

Extent of adoption of irrigation schedule

The data in Table 2 revealed that 68.44% of the respondents had applied less than the recommended number (5 to 6) of irrigations to the potato crop, whereas only 31.56% had given recommended number of irrigations to the potato crop. Sub-division-wise distribution of respondents showed that 36.19% of respondents from Marh, 28.33% from R S Pura, 28.89% from Dayalachak and 20.00% from Samba had given required number of irrigations, whereas 63.81, 71.67, 71.11 and 80.00% of respondents from Marh, R S Pura, Dayalachak and Samba subdivisions had given less than recommended number of irrigations, respectively. Regarding time of irrigation, nearly half (49.34%) of respondents had irrigated the crop at the recommended time, whereas 50.36% of respondents had not irrigated the crop at the recommended time. The data further showed that all the respondents (100%) had followed furrow method of irrigation in potato crop.

Extent of adoption of hoeing and earthing-up practices

Hoeing operation is basic crop practices particularly for tuber crops and should be done twice at 20 to 25 days after planting to pulverize soil for adequate aeration and proper growth and development of the growing tubers. The data in Table 3 indicated that all the respondents had done only first hoeing and none of the respondents had done second hoeing for the control of weeds. 41.33% of them had done hoeing as per recommended time, whereas more than one-half (58.67%) of respondents had deviated from the recommended time of hoeing. Earthing up operation is compulsory in potato as it provides a support to the plant, covers tubers and

Table 2. Extent of adoption of irrigation schedule of potato crop (N = 225).

Irrigation schedule	Sub-division-wise percentage of respondents				Overall percentage of respondents
	Marh (n = 105	R S Pura (n = 60)	Dayalachak (n = 45)	Samba (n =15)	
Number of irrigation					
As per recommendation 5 to 6	36.19	28.33	28.89	20.00	31.56
Not as per recommendation	63.81	71.67	71.11	80.00	68.44
Time of irrigation					
As per recommendation (3 to 4 days after planting)	48.57	50.00	51.11	46.67	49.34
Not as per recommendation	51.43	50.00	48.89	53.33	50.36
Method of irrigation					
Furrow method	100.00	100.00	100.00	100.00	100.00
Flooding	00.00	00.00	00.00	00.00	00.00

Table 3. Extent of adoption of hoeing and earthingup practices by potato growers (n = 225).

Particulars	Sub-division-wise percentage of respondents				Overall percentage of respondents
	Marh (n = 105)	R S Pura (n = 60)	Dayalachak (n = 45)	Samba (n = 15)	
Number of recommended hoeing (2 number)					
1st hoeing	100.00	100.00	100.00	100.00	100.00
2nd hoeing	00.00	00.00	00.00	00.00	00.00
Time of first recommended hoeing (20 to 25 days after planting)					
As per recommended time	40.00	36.67	48.89	46.67	41.33
Not as per recommended time	60.00	63.33	51.11	53.33	58.67
Earthing up	100.00	100.00	100.00	100.00	100.00
As per recommended time 30 to 35 days after sowing	60.00	63.33	51.11	53.33	58.67
Not as per recommended time	40.00	36.67	48.89	46.67	41.33

enhance their quality and size. All the respondents (100%) had followed earthing-up and more than one-half (58.67%) of the respondents had followed earthing-up at the recommended time, whereas 41.33% had deviated from the recommended time.

Extent of adoption of weed control measures and de-haulming practices in potato crop

Weeds check growth of the young plant by devoiding it from soil moisture and nutrients. They are detrimental to all crops and should be controlled initially to avoid weed-crop competition. The data in Table 4 indicated that 67.56% of the respondents had controlled weeds manually and 32.44% had adopted both chemical and manual weed control measures. Sub-division-wise distribution of respondents showed that 53.33% from Marh, 73.33% from R S Pura, 82.22% from Dayalachak and 100.00% respondents from Samba subdivisions controlled weeds manually whereas 46.67, 26.67 and 17.78% of respondents from Marh, R S Pura, and Dayalachak subdivisions had adopted both chemical and manual weed control measures. Regarding dehaulming, it is a practice of cutting and removal of entire arial plant parts, leaving tubers in the soil during aphid free period that is, in the month of December to avoid viral transmission in the tubers *vis a vis* plants. A perusal of data presented in the Table 4 revealed that only 16.00% of the respondents had done de-haulming practice in potato crop for seed purpose. Sub-division wise picture showed that 20.00% respondents from Marh, 16.66% R S Pura, and 11.11% from Dayalachak subdivision had done de-haulming of the crop. None of the respondents from Samba subdivision had adopted this recommended practice.

Table 4. Extent of adoption of weed control measures and de-haulming practice in potato crop (n = 225).

Particulars	Sub-division-wise percentage of respondents				Overall percentage of respondents
	Marh (n = 105)	R S Pura (n = 60)	Dayalachak (n = 45)	Samba (n = 15)	
Method of control					
Manual weed control only	53.33	73.33	82.22	100.00	67.56
Both chemical and manual weed control	46.67	26.67	17.78	00.00	32.44
Dehaulming	20.00	16.66	11.11	00.00	16.00

DISCUSSION

The study revealed that majority of respondents had applied less than recommended number (5 to 6) of irrigations and almost half of the respondents had not followed recommended time of irrigation to the potato crop. The probable reason may be that during Rabi season, the Ranbir Singh Canal, which irrigates whole of the Jammu division is shut down for silt clearance, thereby deviating all the recommendations made for the crop by the concerned SAU. The aforementioned findings are in conformity with those of Hakeem (1998), Shivalingaiah and Nagabhushanam (2004) and Singh et al. (2010) who had reported that majority of the respondents had not followed recommended number of irrigations and interval schedule for irrigating their crops. Regarding methods of irrigation, all of the respondents had adopted recommended method of furrow irrigation. This could be because of farmer's awareness about the furrow method of irrigation. All of the respondents had applied lesser number of hoeings but less than half of the respondents had applied hoeing at the recommended time. The reason might be that during winter season, weed growth might be less and had not posed a severe problem to the crop. Majority of respondents had done earthing-up in potato at the recommended time.

The findings of the study are contradictory to those of Deka and Mukhopadhyay (2008) who found that none of the farmers has adopted earthing-up of potato crop and Sharma (2009) who reported that (50.63%) respondents followed recommended number of hoeings. Majority of the respondents had controlled weeds manually, whereas only 32.44% of the respondents had adopted both chemical and manual weed control measures for controlling weeds in potato crop. The potato growers had done only one late weeding. The probable reason for delay in weeding might be because of closer planting, less irrigation and low dose of manures and fertilizers. The results were also supported by Hakim (1998) and Badodiya et al. (2009) who had reported that majority of the respondents had done only one weeding in potato crop. Only 16% of the respondents had done de-haulming of potato crop because of the reason that they grow the crop for table purpose and not for seed where virus could have spread among the tubers.

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Review

Summer pruning in fruit trees

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Pruning has been practiced for ages in controlling tree size because it has much less stimulating effect on shoot re-growth. The pruning is done to restrict excessive vegetative growth and to maintain a balance between leaf/fruit ratio, fruit size, fruit colour and other quality attributes. Excessive tree vigour can reduce flower bud formation, fruit set and result in reduced fruit quality. Summer pruning by removing the vigorous growing shoots increase the light intensity in cropping zone and colour intensity. Late summer pruning also reduce the growth due to reduction in photosynthetic capacity and ultimately carbohydrate reserve by reducing the leaf area index and the spread of the canopy.

Key words: Pruning, fruit trees, growth, yield.

INTRODUCTION

Pruning may be defined as the removal of plant parts to achieve a desirable architecture of the canopy and also using the foliage density by removing the unproductive branches of fruit trees. Summer pruning in apple orchards can be traced back to the 17th century and has scientific attention since 1903 (Marini and Barden, 1987). For vigour control, pruning is the most important operation conducted in dormant season, when the leaf fall takes place. This operation requires skilled labour, which is time consuming and costly. It is the means of diverting a portion of plant water and nutrients from one part of growing point to another. The pruning is done to restrict excessive vegetative growth and to maintain a balance between leaf/fruit ratio, fruit size, fruit colour and other quality attributes. Excessive tree vigour can reduce flower bud formation, fruit set and result in reduced fruit quality. It increases auxin activity by about 60%, gibberellin by 90% and cytokinin by 90% (Grochowska et al., 1984). Pruning increases photosynthetic translocation to fruits and roots which regulates flower bud formation. With the increase in knowledge of the importance of light interception and apple orchard management (Jackson, 1980), the interest in the effects of summer pruning has been revived.

By removing the part of the extension shoots and leaves, summer pruning improves light penetration and distribution within the canopy (Lakso et al., 1989) and improves fruit colour. Removal of apical portions of shoots by pruning changes the hormonal status between the meristems which results in stimulation of lateral buds, induction of branching and increment in photosynthesis of basal leaves (Mika, 1986). The relationship between vegetative and reproductive growth influences the amount and quality of fruits produced by an apple tree.

EFFECT OF SUMMER PRUNING ON VEGETATIVE GROWTH CHARACTERISTICS

Pruning has been practiced for ages in controlling tree size because it has much less stimulating effect on shoot re-growth (Mika and Krzewinska, 1995). Mizutani et al. (2000) reported that the earlier summer pruning resulted in the greater shoot length and shoot numbers in apple trees. Bruno and Evelyn (2001) reported that shoot tipping in cherimoya significantly decreased shoot length

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according to the date it was done. In Shimizuhakuto cultivar of peach, the shoot growth in light pruned trees ceased by end of May, while in heavy pruned trees, the shoots continued to elongate until the end of June (Fukuda et al., 2002). Zamani et al. (2006) observed that by conducting summer pruning on apple cultivars Golab and Shafi-Abadi on M9 rootstock, trunk cross sectional area was positively correlated with annual shoot number, total length of annual shoots, tree volume and dormant pruning weight. Summer pruning treatments effectively reduced the measured vegetative characters. They further reported that the treatment was most effective when conducted 90 days after full bloom. Hassani and Rezaee (2007) conducted field studies on the peach cultivars, Anjiri and Mahalli. Three pruning intensities namely, one half, one third and one fourth cutting back of the bearing shoots were applied on the trees, it was found that there was a significant increase in vegetative growth with the heavy pruning. Melouk (2007) stimulated vegetative growth of Succary Abiad mango cv. by pruning. Salem et al. (2008) showed that the vegetative growth of Baldy mandarin trees was improved by pruning.

Demirtas et al. (2010) reported that the pruning applications significantly affected both shoot diameter and length. The highest shoot diameter and length were obtained from pre-harvest summer + winter pruning application as 8.52 mm and 77.84 cm, respectively. The highest leaf area was determined as 39.43 cm^2 in post harvest pruning treatment. Depending upon pruning severity, stage of plant development and environmental conditions like nutrient supply, soil moisture and light, summer pruning may have a dwarfing or an invigorating influence on fruit trees as compared to winter pruning. Summer pruning suppresses shoot growth and shoots were shorter on summer pruned trees than control.

EFFECT OF SUMMER PRUNING ON FRUIT SET AND YIELD

Summer pruning resulted in favourable influence in relation to better fruit set and yield in pruned mango trees (Lal et al., 2000; Sharma and Singh, 2006). Ingle et al. (2001) reported that medium pruning recorded the highest value for the number of flowers per shoot of acid lime trees. Sharma and Chauhan (2004) recorded the highest fruit yield in lightly pruned trees where 25% of current season's growth was removed than the moderate and severely pruned trees where 50 and 75% of the current season's growth were removed, respectively in peach. Kumar et al. (2005) reported in Sharbati, Flordasun and Prabhat cvs. of peach that among the three pruning intensities namely, light, medium and severe; light pruning induced early flowering and also increased the number of flowers as compared to other pruning treatments. Rather (2006) reported that strong pruning delayed flowering by 6 to 9 days, increased fruit set (64.75 and 60.21%) as compared to 36.95 and 25.16% in control during 2004 and 2005, respectively. However, maximum fruit yield (117.07 and 132.47 kg $tree^{-1}$) was attained by medium pruning regime as compared to 93.63 and 98.93 kg $tree^{-1}$ fruit yield in control during 2004 and 2005 in Red Delicious apple. Robinson et al. (2006) reported that the yield per tree was largely affected by the severity of pruning and the yield was greatest in the least pruned peach trees. Shaban (2009) observed that moderate pruning and GA_3 at 50 ppm proved to be the most effective treatment for improving yield of Zebda mango trees in the off-year season. Demirtas et al. (2010) reported that the highest average yield considering trunk cross-sectional area was obtained as 0.34 kg cm^{-2} from pre-harvest summer pruning treatment and the highest share of flower bud was observed as 68.29% in pre-harvest summer + winter pruning treatment in apricot.

Mohamed et al. (2011) reported that shortening 1/3 branches level treatment gave the highest yield (33.62 kg/tree) followed by tipping (31.47 kg/tree), shortening 1/2 branches level (21.72 kg/tree) than control trees (19.41 kg/tree) in plum. Summer pruning increased light penetration within the tree canopy which strengthen spurs and increase flower bud formation. Also, buds break at the base of pruned shoots and develop into fruiting spurs due to summer pruning. Summer pruning performed on growing shoots removed apical dominance, released lateral buds from correlative inhibition and changed tree form and construction which in turn, increased flower bud initiation from lateral buds and increased the yield.

EFFECT OF SUMMER PRUNING ON RETURN BLOOM

Miller and Byers (2000) reported in peach cv. Balke that the return bloom was lowest in trees which were left unpruned or were severely pruned than the light and heavily pruned trees. Li et al. (2003) reported that summer pruning in apple alone did not affect the return bloom or root growth within commercial canopy ranges. Li and Lakso (2004) reported that within commercial cropping ranges, light and moderate summer pruning alone in apple did not affect return bloom or root growth, however, the potential negative effect of summer pruning on fruit growth, return bloom and fine root survival can be predicted through their relationships with physiological factors. Maas (2005) noticed that summer regrowth caused the loss of terminal flower buds in 'Conference' and 'Doyenne du Comice' pears.

EFFECT OF SUMMER PRUNING ON FRUIT PHYSICAL CHARACTERISTICS

Severely pruned trees produced heavier and large sized fruit, with a higher percentage of fruit in 80 mm diameter of large category (Bound and Summers, 2001). Bruno and Evelyn (2001) noticed that shoot tipping in cherimoya at 10 buds and its combination with bark girdling resulted in an increase of 25% in fruit weight. Sonali et al. (2001) found that different levels of pruning increased fruit weight in litchi. Kaundal et al. (2002) also reported the enhanced fruit size with ascending pruning severities in Pratap peach trees. Rather (2006) reported that highest fruit volume (280.57 and 305.06 cm^3) was attained by medium pruning regime as compared to 102.30 and 111.17 cm^3 fruit volume in control during the years 2004 and 2005, respectively in 'Delicious' apple. Firmness was recorded more in light pruning whereas organoleptic rating was found superior by medium pruning in both years of study in Red Delicious apple. Hossain et al. (2006) observed that fruit maturation was accelerated in summer-pruned peach trees. Mohamed et al. (2011) reported that the highest values of weight, size, length, diameter, shape and flesh thickness were recorded by shortening 1/3 branches level followed by shortening ½ branches level, tipping than control trees in both seasons in plum.

Fruit size, weight and volume were similarly increased by summer pruning. Pruning decreased the fruit load and as the number of fruits was less, the available food material reached the individual fruit in sufficient quantity.

EFFECT OF SUMMER PRUNING ON FRUIT COLOUR

Prakash and Nautiyal (1994) also noticed greater red colour from the severely pruned peach trees than the moderately and lightly pruned ones. Francisconi et al. (1996) observed in peach cultivar Marli that removal of more than 50% of current shoots significantly increased fruit surface colouration. Singh et al. (1997) also reported significant effect of pruning on colour development in peach fruits. Thinning cuts and heading cuts made it possible to pick a large number of total and highly coloured fruits earlier than following heading cuts in 'Yataka Figi' (Yongkoo et al., 2000). Li et al. (2003) reported that by conducting summer pruning, the canopy size can be controlled and light availability to fruit for red colour development can be improved without undesirable post pruning regrowth by summer pruning. Dussi et al. (2004) when conducted summer pruning in Red Delicious apple tree noticed an increase in red colour. Rather (2006) noticed that fruit colour was superior in medium pruned in Red Delicious apple. By conducting summer pruning, the canopy size can be controlled and light availability to fruits for red colour development can be improved without undesirable post pruning regrowth by summer pruning.

EFFECT OF SUMMER PRUNING ON FRUIT CHEMICAL CHARACTERISTICS AND STORAGE

Sonali et al. (2001) revealed that 5 levels of pruning in litchi trees increased T.S.S. and total sugars and ascorbic acid content. In Redhavan peach trees, the buds of pruned plants had higher soluble sugars and starch content than the unpruned ones (Vitagliano et al., 2001). Kaundal et al. (2002) reported that the TSS acid ratio and total sugar in peach was enhanced with increase in pruning severity. Mahajan and Dhillon (2002) observed that the pruning at 75% produced the highest TSS; whereas, the highest acid content was noticed in unpruned plants of Shan-e-Punjab peach. Singh and Chauhan (2002) reported in July Elberta peach that the total soluble solids content increased with increasing pruning severity. Sharma and Chauhan (2004) further reported that heavy pruning where cutting back the annual shoots to 75% of their original length was done in July Elberta peach produced higher TSS, acidity and total sugars as compared to pruning treatment where cutting back of annual shoots to 25 and 50% was performed. Rather (2006) reported that TSS and total sugar was found superior by medium pruning and acidity was noticed more in control in both years of study in 'Red Delicious' apple. Hossain et al. (2006) observed that fruit maturation was accelerated in summer-pruned peach trees, which resulted in higher soluble solids content (SSC) and lower titratable acidity (TA) in the fruit. Qing et al. (2006) reported in Kyolea cultivar of peach that the fruit soluble solids content of 15 cm branch was slightly higher than that of branches with 35 to 60 cm and more than 60 cm in length.

Hassani and Rezaee (2007) reported an increase in fruit TSS of peach with the increase in the pruning severity. Mercier et al. (2008) reported that manual pruning enhanced the fruit quality measured in terms of increased total soluble solids in peach. The increased rate of photosynthesis led by more light penetration into the interior tree canopy increased the soluble solids in fruits harvested from pruned trees. Summer pruning accelerates fruit maturation which resulted in higher soluble solid content and lower titratable acidity. Summer pruning significantly enhanced fruit calcium which resulted in decrease in incidence of calcium related disorders like bitter pit, cork spot, thereby extending the shelf life of fruits. Summer pruning has the potential to reduce the competition between shoot growth and fruit for available calcium which increased calcium levels in fruits.

EFFECT OF SUMMER PRUNING ON EVAPOTRANSPIRATION

There may be other advantages of summer pruning beyond fruit colour and tree size control. Removing leaves by summer pruning can be expected to reduce total canopy water loss (transpiration), and consequently improve tree water status. In Washington State, heavy summer pruning has been used to help pear and peach orchards survive in severe drought seasons (Li et al., 2001). Therefore, in dry years or areas, summer pruning might help relieve drought-induced reductions in fruit growth.

EFFECT OF SUMMER PRUNING ON CANOPY WATER LOSS AND WATER STATUS

Summer pruning reduced canopy transpiration rate which indicates that less water is lost through the leaves after summer pruning. Tree water status for fruit expansion is improved after summer pruning (Li et al., 2001). Therefore, for overall fruit growth, improved tree water status might compensate for the shortage of carbohydrate supply in drought years. The reduction in canopy transpiration after summer pruning, however, might affect the impact of carbohydrate imbalance by improving tree water status.

CONCLUSION

Summer pruning caused minimum vegetative growth which increased fruit yield by way of increasing flower bud formation and return bloom as well. Growth has been suppressed, the year of pruning due to reduced supplies of photosynthates or growth regulators from tree top during the late summer. Growth might also be suppressed due to the restricted root system following summer pruning. Summer pruning increased the light exposure of spur leaves in the interior apple canopy. Previous canopy shade reduced the apparent photosynthetic ability of the interior leaves. If summer pruning is done correctly, fruit colour development could be significantly improved without any other losses of yield or quality. The fruits retained better quality characteristics in terms of size, weight, volume, colour change, firmness, organoleptic rating, physiological loss in weight, spoilage, acid content, total soluble solids, sugars (total, reducing and non-reducing sugars) and calcium content due to summer pruning.

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Full Length Research Paper

Variation, correlation and path coefficient analyses in seed yield and related characters in local accessions of African Yam Bean (*Sphenostylis stenocarpa*) from Southern Nigeria

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Local accessions of African Yam Bean, a poorly studied and under-utilized but important food crop, from Abia, Akwa Ibom and Cross River states of Southern Nigeria were studied for variation in seed yield and pod characteristics. Correlations were carried out on the studied characters to determine the degree of mutual association among them while path coefficient analysis was used to partition the correlation coefficients into their direct and indirect effects on seed yield. Results revealed that significant differences (p<0.01) exist among the accessions with respect to the studied characters. Mean number of seeds per pod ranged from 13.27 to 18.87; seed weight per pod from 3.19 to 6.21g; weight of 100 seeds from 22.86 to 36.72g; pod length from 21.67 to 36.82 cm and pod width ranged from 0.79 to 1.05 cm. Number of seeds per pod and pod length had significant positive association with seed weight per pod. Pod width also correlated positively with seed weight in some accessions. Positive direct effects on seed weight per pod were obtained with number of seeds per pod and pod length. The results taken together revealed significant variations in the accessions and provide evidence for effective selection which is a prerequisite for genetic improvement.

Key words: *Sphenostylis stenocarpa,* accessions, variation, correlation, path coefficient analysis.

INTRODUCTION

Food security and sustainability are currently of serious global concern and unfortunately, many indigenous African crops that show promise in providing nutritional securities are presently neglected and under-utilized (Adewale and Odoh, 2012). African yam bean (*Sphenostylis stenocarpa* (Hoscht ex. Rich) Harms), despite its enormous nutritional potential, represents one of such under-utilized crops in Nigeria, Ghana and many tropical African countries (Amoatey et al., 2000; Olasoji et al*.,* 2011; Akande et al., 2012). In Nigeria, it is cultivated mainly in the southern and middle belt regions, but is also found in other West African countries including Ghana, Togo, Cote'd Ivoire, Cameroon and Central Africa (Klu et al*.,* 2001).

African yam bean is used as food or food components and provides two consumable products: The tuber which grows as the root source and the actual yam beans which develop in pods above ground (Olasoji et al*.,* 2011). Like

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other grain legumes, African yam bean is an excellent food, low in fats and rich in protein, carbohydrate, fibre, minerals and vitamins with relatively high contents of anti nutrients (Akande et al*.,* 2012).

There is a general dearth of literature on African yam bean research and development; however, some important studies have been documented. Olasoji et al*.* (2011) reported genetic variability in its seed quality; Akande (2009) and Popoola et al*.* (2011) reported on the morphological characteristics of the crop. Ajibade et al*.* (2005) reported on the nutritive and anti-nutritive factors in African yam bean while Uguru and Madukaife (2001) reported the protein content.

Genetic improvement of this crop would among others, require that variations in seed yield and related characters among local accessions be understood for effective hybridization. Yield however is a complex character which is determined by several factors and as such, it is also necessary to study the interrelationships between yield and these related characters so that important characters that could be used as selection criteria for crop improvement would be determined. In this wise, correlation studies are useful in measuring the mutual association between characters. Alongside correlation is the path coefficient analysis which is a veritable tool in a breeder's hand for partitioning the correlation coefficients into direct and indirect effects so that the contribution of each character to a dependent character like yield could be estimated (Cyprien and Kumar, 2011). In other words, both the direct and indirect effects of related characters on yield must be considered if we want to know the total effects a change in such characters will have on yield.

In view of the critical need to genetically improve African yam bean as well as contribute literature to this poorly studied but important food crop, this study was aimed at examining some local accessions of African yam bean from southern Nigeria for variations in pod and seed yield characters, measuring the degree of association (correlation) between seed yield and related characters as well as partitioning the computed correlation coefficients into their direct and indirect effects on yield.

MATERIALS AND METHODS

Mature and dry pods of African yam bean accessions were collected *in situ* from three (3) different states (Abia, Akwa Ibom and Cross River) of southern Nigeria. One accession (Umudike) was collected from Abia state, three accessions (Abak, Etim Ekpo and Ikot Abasi) from Akwa Ibom state and two accessions (Biase and Obubra) from Cross River state. A random sample of fifteen (15) pods from each accession were studied and data collected on the following pod and seed characters: Pod length (cm), pod width (cm), number of seeds per pod, weight of seeds per pod (g), weight of 100 seeds (g). Pod length was obtained by measuring from peduncle stalk end to pod beak end, pod width was measured with a vernier caliper while a sensitive electronic balance was used to take accurate measurement of weights.

Statistical analyses

Data obtained from the pod and seed yield characters for the different accessions were laid out in a completely randomized design (CRD) with fifteen replications and analyzed using a one-way analysis of variance. Significant means were separated using the least significant difference (LSD) test. The intensity of linear relationship between the characters studied was determined using the Karl Pearson's coefficient of correlation, while path coefficient analysis was estimated by solving sets of simultaneous equations indicating the basic relationship between correlation and path coefficients according to Cyprien and Kumar (2011).

RESULTS

Statistical analysis of the mean values in the pod and seed yield characters of the studied accessions revealed significant variations among them (Table 1). The mean number of seeds per pod ranged from 13.27 to 18.87 ($p<0.01$). Abak and Umudike accessions had the lowest mean number of seeds per pod with 14.20 and 13.27, respectively. All other accessions had a mean number of seeds per pod of above 15 with the highest of 18.87 seeds per pod observed in Ikot Abasi accession. Mean seed weight per pod and weight of 100 seeds ranged from 3.19 to 6.21 and 22.86 to 36.72 g respectively. Accession from Obubra had heavier seeds generally followed by Biase accession while other accessions appeared to be weaker in this character with Etim Ekpo and Abak accessions having the lightest seeds. Mean pod length and width for the accessions ranged from 21.67 to 36.82 and 0.79 to 1.05 cm respectively. Ikot Abasi accession had the highest pod length relative to other accessions. Pod lengths of the remaining accessions did not differ significantly from one another except for Umudike accession which had the least pod length. Pod widths were bigger for Obubra and Ikot Abasi accessions, followed by Umudike, Etim Ekpo and Biase, while Abak accession had the least pod width.

Correlation coefficients for some characters of the African yam bean accessions evaluated are shown in Table 2. For all the accessions, number of seeds per pod had significant and positive correlation with seed weight per pod. Pod lengths also correlated positively and significantly with seed weight per pod in all the accessions except for Biase where correlation was positive but insignificant. In the path coefficient analyses, seed weight per pod was considered as the artifact of all the causal factors (number of seeds per pod, pod length and pod width) and the correlation coefficient of each causal factor with the seed weight per pod was partitioned into their direct and indirect effects as presented in Table 3.

DISCUSSION

Genetic variability is useful in facilitating the development

Table 1. Variation in pod and seed yield characters in local accessions of African yam bean from southern Nigeria.

Accession	No. of seeds per pod	Seed weight per pod (g)	Weight of 100 seeds (g)	Pod length (cm)	Pod width (cm)
Abak	14.20±0.85^{cd}	3.19±0.21^{c}	22.86±0.22^{e}	25.75±1.03^{c}	0.79±0.04^{d}
Biase	16.67±0.61^{b}	4.86±0.30^{b}	29.76±0.39^{b}	27.59±0.76^{bc}	0.87±0.02^{c}
Etim Ekpo	15.53±0.70^{bc}	3.54±0.18^{c}	23.11±0.24^{e}	27.65±0.76^{bc}	0.89±0.02^{c}
Ikot Abasi	18.87±0.58^{a}	4.86±0.20^{b}	26.47±0.29^{d}	36.82±0.51^{a}	0.99±0.02^{ab}
Obubra	16.73±0.69^{b}	6.21±0.33^{a}	36.72±0.11^{a}	28.68±0.61^{b}	1.05±0.03^{a}
Umudike	13.27±0.86^{d}	3.65±0.30^{c}	27.80±0.46^{c}	21.67±0.64^{d}	0.92±0.03^{bc}
LSD	2.02	0.73	0.95	2.07	0.07

Means with different superscripts within each column differ significantly ($p<0.01$) from one another.

Table 2. Inter-character correlations between seed yield and related characters in six accessions of African yam bean from southern Nigeria.

Accession	Character	SW	NS	PL	PW
Abak	SW	1	0.887**	0.830**	0.635*
	NS		1	0.783**	0.408^{NS}
	PL			1	0.707**
	PW	1	0.655*	0.400^{NS}	1
Biase	SW		1	0.367^{NS}	0.199^{NS}
	NS			1	-0.052^{NS}
	PL				-0.149^{NS}
	PW				1
Etim Ekpo	SW	1	0.812**	0.709**	-0.665**
	NS		1	0.561^{NS}	-0.317^{NS}
	PL			1	-0.024^{NS}
	PW				1
Ikot Abasi	SW	1	0.602*	0.799**	0.576*
	NS		1	0.440^{NS}	-0.032^{NS}
	PL			1	0.567*
	PW				1
Obubra	SW	1	0.602*	0.555*	0.608*
	NS		1	0.303^{NS}	0.275^{NS}
	PL			1	0.025^{NS}
	PW				1
Umudike	SW	1	0.841**	0.813**	0.570*
	NS		1	0.751**	0.340^{NS}
	PL			1	0.157^{NS}
	PW				1

SW, Seed weight/pod; NS, number of seeds/pod; PL, pod length; PW, pod width.*, ** represent significance at 5% ($p<0.05$) and 1% probability level ($p<0.01$) respectively; ^{NS} represents insignificance.

of a large number of new genotypes through hybridization by transfer of useful genes, thus maximizing the use of such available genetic potentials in boosting food production for sustainable food security (Olasoji et al., 2011). Interestingly, all the studied accessions of African yam bean revealed such variability, but also some similarity. Results obtained from the mean seed yield indicate that Ikot Abasi accession would be useful in genetic improvement for seed quantity. The range of number of seeds per pod reported in this paper is,

Table 3. Path coefficients showing direct and indirect effects of yield related characters on seed yield in local accessions of African yam bean from southern Nigeria.

Accession	Character	Correlation with SW	Direct effect on SW	Indirect effects via NS	Indirect effects via PL	Indirect effects via PW
Abak	NS	0.887	0.729	-	0.032	0.126
	PL	0.830	0.041	0.571	-	0.218
	PW	0.635	0.309	0.297	0.029	-
Biase	NS	0.655	0.586	-	0.082	-0.014
	PL	0.400	0.224	0.215	-	-0.039
	PW	0.199	0.263	-0.030	-0.033	-
Etim Ekpo	NS	0.812	0.367	-	0.275	0.170
	PL	0.709	0.490	0.206	-	0.013
	PW	-0.665	-0.537	-0.016	-0.012	-
Ikot Abasi	NS	0.602	0.437	-	0.177	-0.012
	PL	0.799	0.401	0.192	-	0.206
	PW	0.567	0.363	-0.014	0.227	-
Obubra	NS	0.602	0.328	-	0.134	0.139
	PL	0.555	0.443	0.099	-	0.013
	PW	0.608	0.507	0.090	0.011	-
Umudike	NS	0.814	0.337	-	0.376	0.128
	PL	0.813	0.501	0.253	-	0.059
	PW	0.570	0.377	0.115	0.079	-

SW, Seed weight/pod; NS, number of seeds/pod; PL, pod length; PW, pod width.

however, higher than those reported by Akande et al. (2012) from western Nigeria (8.40 to 15.93). With regards to mean seed weight per pod, Obubra accession along with that of Biase would be useful for seed yield improvement in African yam bean. Akande et al. (2012) reported a bit lower range of 19.6 to 31.27 g for 100 seed weight in western Nigeria. Longer pods were observed in Ikot Abasi accession. This trend is expected since this accession had significantly more number of seeds per pod than others. However, interestingly, pod lengths for the accessions studied in this paper are higher than those reported by Akande et al. (2012) from western Nigeria with range of 16.00 to 25.0 cm. The significantly higher pod width reported for Obubra accession may be naturally expected since the accession had significantly heavier seeds than the rest and the bulk of each seed would require more space in the pod. The general trend of these results agrees with the reports of Akande (2009), Popoola et al. (2011) and Olasoji et al. (2011) that significant variations occur in African yam bean accessions for many characters including flowering and reproductive characters, and seed quality. The results obtained from the correlation analyses provide evidence that selection for number of seeds per pod could lead to simultaneous improvement in seed yield for African yam bean. Akande et al. (2012) reported this same trend for the accessions they studied from southern Nigeria. Pod length correlated positively with seed weight per pod in most accessions but one. This indicates that longer pods in African yam bean are more often than not, likely to result in higher seed weights. Pod widths also correlated positively and significantly with seed weight in some accessions. Taken together, it is evident that both pod lengths and widths are contributory to seed weight in African yam bean and could be selected in attempts to improve seed yield in the plant especially for the accessions where they show such promise. In Abak and Umudike accessions, pod lengths correlated positively and significantly with number of seeds per pod, but interestingly, this was not the case with the other accessions where such correlations were though positive but insignificant. This result seems to suggest that longer pods may not necessarily strongly translate to more seed content in African yam bean. Path coefficient analyses showed evidently that number of seeds per pod exhibited the highest direct positive effect on seed weight in Abak (0.729), Biase (0.586) and Ikot Abasi (0.437) accessions. This direct effect is along with all other indirect positive effects of low magnitude through pod length and pod width (negative for Biase accession). According to a statistical test for relative importance of path coefficients by Cramer and Wehner (2000a), the direct positive effect of number of seeds on seed weight for Abak accession would be considered strong, but weak for Biase and Ikot Abasi accessions. Pod length exhibited the highest direct positive effect on seed weight in Umudike and Etim Ekpo accessions, while pod width had the highest direct positive effect on seed weight in Obubra accession.

Conclusion

The present study revealed significant differences in all the pod and seed yield characters evaluated for the African yam bean accessions. Obubra and Biase accessions were identified as superior in terms of seed weight while Ikot Abasi, Obubra and Biase accessions were superior to others in seed quantity per pod. Number of seeds per pod, pod length and pod width were all closely associated to seed weight in varying magnitudes for the accessions. The order of magnitude of positive direct effects of these characters on seed weight per pod could be summarized as: Number of seeds per pod > pod length > pod width. The findings from this study revealed that the interesting variations in pod and seed characters of African yam bean as well as the relative contribution of each character on seed yield (weight) would assist in the genetic improvement of this crop.

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The effect of comboplough on some soil physical properties of Universiti Putra Malaysia Research Park

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A disk plough combined with a set of rotary blades (comboplough) for land preparation has been designed, fabricated and tested. The concave disk cut and inverted layers of soil to bury surface material. The soil in contact with the surface of disk would be cut and pulverized by the rotary blades. Normal multiple tillage operations were reduced to a single pass and thus reduced the number of field trips as compared to conventional tillage practices resulting in a potential reduction of soil compaction, labor, fuel cost and time. The comboplough was tested in the Serdang sandy clay loam soil texture at Universiti Putra Malaysia Research Park. The treatments consisted of three types of blade (straight type or S blade, C-shaped and L-shaped) and three rotary speeds (130, 147 and 165 rpm). Mean Weight Diameter Dry basis (MWD_d), mean weight diameter wet basis (MWD_w), stability index (SI), instability index (II), 2 to 8 mm aggregate size distribution (ASD_{d8}) and 0 to 100 mm aggregate size distribution (ASD_{d100}) were determined and analyzed. The results indicated that no significant differences were noted between types of blade. However, the rotational speeds had significant effects on selected parameters.

Key words: Tillage, combined implement, disk plough, rotary blade.

INTRODUCTION

The plough is as old as agriculture which originated from 10 to 13 million years ago in the fertile crescent of the Near East, mostly along the Tigris, Euphrates, Nile, Indus and Yangtze River valleys, and were introduced into Greece and Southeastern Europe 8000 years ago (Lal et al., 2007). Tillage is one component in any system of soil management for crop production and is a process of applying energy to the soil to change its physical condition by disturbing it. Tillage processes are used in crop production for different reasons, such as loosening soil to create a seedbed or soil pulverization for better root zone, moving soil to change the micro topography, or mixing soil to incorporate amendments (Zhong et al., 2010). Lobb et al. (2007) reported that tillage has been and will always be an integral part of crop production. They further stated that tillage can result in the degradation of soil, water and air quality. Tillage is the most important primary activity for crop production. In addition, it is one of the highest power-required processes of the agricultural production and the high cost of energy has encouraged farmers to find alternative economic tillage methods (Bayhan et al., 2006). Tillage operation is also defined as a procedure for breaking up soil; the soil failure depends largely upon the soil

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Figure 1. A comboplough.

(a) (b) (c)

Figure 2. Straight blade, S (a), C-shaped blade (b) and L-shaped blade (c).

properties, tool parameters and cutting speed (Zhong et al., 2010). The cost and the timeliness of operation assume critical importance while deciding the type of tillage tools. Godwin (2007) said that the cost of tillage operation is a vital component to determine farm profitability and recent years have seen a significant move to reduce tillage operation. The great part of energy consumption in mechanized agriculture is related to tillage operation. Operations simultaneously utilizing two or more different types of tillage tools or implements to simplify, control or reduce the number of operations over a field are called combined tillage. Machines for tillage operation usually pass the farm four times or more which causes soil compaction, increases cost of labour and energy. The compression of soil causes reduction of the moisture penetration, soil oxygen capacity, penetration of root in the soil, organic materials capacity in soil and increasing energy consumption (Tebrügge and Düring, 1999).

Most of the primary tillage operation is for unsettling the compression of soil and root growth. In this regard, Ruci and Vilde (2006) on their research stated that ploughing is one of the most power-consuming and expensive processes in agricultural production. Craciun et al. (2004) on their research reported some advantages about combined machines for seedbed preparation and sowing. Using conventional technologies, with successive tillage implements across the land, it takes a lot of time, the loss of the soil moisture and sometime because of heavy rains, snow and bad weather, could impede sowing and crop establishment. Cesnieks et al. (2001) and Vilde (1998, 1999) evaluated the possibilities and efficiency of soil tillage minimization and they concluded that, it is one of the most power-consuming and expensive processes in agricultural production. They reported that tillage requires 180 to 320 kWh/ha, which corresponds to 50 to 80 kg of fuel per hectare of the land tilled and makes 20 to 25% of its total consumption in agriculture. With the present technologies, the cost of soil tillage operation ranges between 45 to 58 USD/ha. In terms of draft, Javadi and Hajiahmad (2006) reported that draft and clod mean weight diameter (MWD) significantly decreased when combined tillage operation is done compare to single operation with many pass. The past research work did not consider the combined effect of disk plough and rotary blades on farm. In this regard, Ahmad and Amran (2004) studied the energy prediction model for disk plough combined with a rotary blade in wet clay soil. In order to produce cheaper agricultural products, it is necessary to reduce expenditure. The concept of disc plough combined with rotary blade machine has the following advantages; higher degree of soil crumbling, better mixing of soil and mineral fertilizer, improved parameters of work on heavy soils, the guarantee of complete preparation of the field, reduction of draft and wheel slip, reduces soil compaction, energy consumption, fuel consumption, decreases labour and machinery cost.

Disc ploughs are simultaneously utilized to prepare an adequate seedbed and bury crop residues. They are particularly adapted for use in hard-dry soils, shrubby or bushy land. They are also utilized in clay soil for reduction of energy consumption in tillage, soil compaction and structural degradation due to vehicular traffic. This paper describes a study on the design, development and performance of a comboplough to replace current two-pass or three-pass tillage treatments with one-pass. The potential benefit with current one-pass tillage treatment would be saving in fuel, labour and machinery cost.

MATERIALS AND METHODS

Tractor and tillage apparatus

A comboplough has four essential parts which include a chassis, a disk plough (Figure 1), a set of rotary blades (Figure 2) and a transmission system (Figure 3). The comboplough is attached to a tractor three point linkage system and driven by the tractor power-take-off shaft (PTO). Power is transferred from the PTO to the gearbox (Figure 2). The drive direction is changed by 90° at the horizontal shaft to the rotary blade shaft. A clutch safety system is placed between the universal joint and the gearbox to prevent overload. The disk implement consists of standard disk having 61 cm diameter (Tooth, 1998). The position of rotary blade was determined according to the upward soil movement at the end of the disk (Ahmad and Amran, 2004). The rotary shaft has three kinds of blades: straight (S), C-shaped and L-type (Figure 2). A

Figure 3. Transmission system.

Figure 4. Adjustment and positioning of tractor travel speed.

63.4 kW John Deere 6405 (PTO power 51 kW) was used for the tillage experiments. The tractor has static weight distribution of 40% front and 60% rear with total mass of 3891 and 180 kg balancer (6 × 30 kg). The front tires were type radial 12.4 to 24 single operated at 220 kPa inflation pressure while the rear tires were radial 18.4 to 34 single operated at 160 kPa inflation pressure.

Tillage site

The experiments were carried out at the University Putra Malaysia Research Park, Serdang Selangor, Malaysia, on three different plots with 675 m^2 size in the year 2010/2011, on a clay loam soil with average texture of 28.73% sand, 28.32% clay and 43.7% silt, longitude 101°, 42.912´E, latitude 2°, 58.821´N and an altitude of 40 m above sea level. The experimental site has an average annual rainfall of 2548.5 mm with maximum and minimum temperatures of 33.1 and 23°C, respectively. The soil penetration resistance in each experimental plot was determined using a Penetrograph (80 mm long and 10 mm cone diameter) at depth between 0 to 80 mm.

Test procedure

The test was performed based on 2 × 3 factorial treatment in Randomized Complete Block Design (RCBD) with three replications. Block dimensions were 25 × 27 m^2. Clod mean weight diameter was determined using different sieve sizes (8, 4.75, 2.8, 2, 0.5, and 0.3 mm) in three replications after operation. The main plots were allocated to rotary speeds (130,147 and 165 rpm) and sub plots were allocated to the three types of blades namely, straight blade (S), C-shaped and L-shaped. Aggregate stability or stability index (SI) was measured using a wet-sieving apparatus to determine the mean weight diameter, wet basis (MWD_w) and dry-sieving to determine the mean weight diameter, dry basis (MWD_d). The method of wet-sieving was adapted from Kemper and Rosenau (1986). The wet-sieving apparatus duration was 10 min and 50 oscillations per minute and SI was calculated using the following formula:

Instability Index (II) = $MWD_d - MWD_w$

Stability index (SI) = 1÷ instability index (II)

Experiments were conducted to determine the influence of various types of blades and rotational speeds on selected soil physical properties. The soil physical characteristics investigated were MWD_d, MWD_w, to find out the SI, II and percentage of aggregate size distribution for aggregates between 2 and 8 mm (ASD_{d8}). Clod mean weight diameter (MWD_{d100}) was determined using different sieve sizes (100, 50, 14, 6.3 mm) in three replications after operation using sieve size of 100 mm and below. The tillage depth for disk plough was 20 cm. The tractor PTO speed of 540 rpm was reduced to 216.5 rpm using a gearbox. The rotary blade speeds of 130,147 and 165 rpm were obtained by changing the adjustable gear sprockets (13:23, 14:22 and 15:21) in the transmission system (Figure 3). The travel speed used for all treatments was 7.2 km h^{-1}. This travel speed was achieved by adjusting engine throttle (1500 rpm) and gearbox position (A-2) at fixed setting (Figure 4). The analysis of variance (ANOVA) and protected Duncan's new multiple range test were used to analyze the data using the statistical analysis systems (SAS) 2005 software.

Measurements of soil characteristics

Twenty-seven soil samples were collected from the field during the tillage experiments from each plot at depths of 0 to 15 and 15 to 30 cm. Soil samples were classified by mechanical analysis using the pipette method.

RESULTS AND DISCUSSION

Table 1 presents the result obtained from the mechanical analysis for the soil sample using pipette principles. The soil classification was achieved by USDA textural classification system. The experimental soil sample was found to be sandy loam (Table 1 and Figure 5). Figure 6 shows the soil penetration resistance of different experimental plots at different depths. The maximum soil resistance of 380 N/cm^2 was found in plot "A" at the 75

Table 1. Soil particle size of the field at the University Research Park for a Serdang clay loam.

Site	Clay (%)	Sand (%)	Silt (%)
A	33.74	40	26.82
B	25.64	14.53	59.83
C	25.77	31.67	42.56
Average	28.38	28.73	43.07

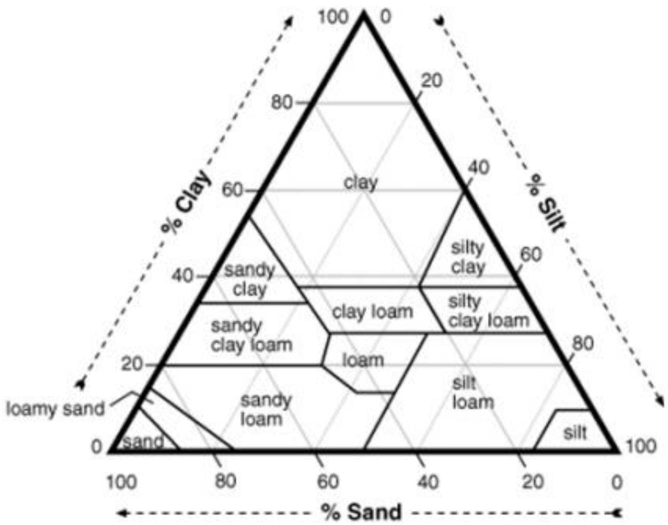

Figure 5. USDA textural classification system (percent sand ≥2 to 0.050 mm, percent silt = 0.050 to 0.002 mm, and percent clay is finer than 0.002 mm) (Teh and Jamal, 2010).

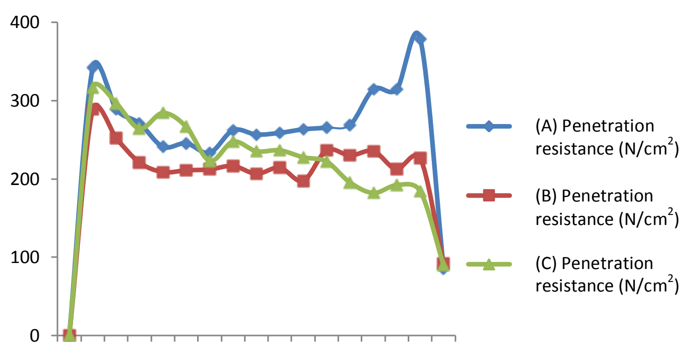

Figure 6. Soil penetration resistance at different sampling plots.

mm depth. Tables 2 and 3 show the relationships between types of rotary blades, rotational speeds and physical characteristics of soil. Statistical analysis presented indicates that there were no significant differences between types of blades on MWD_d. The effects of different blades were not significant on MWD_w; however, it was noted that the C-shaped blade had minimum MWD_w and the straight blade, S, had maximum MWD_w (Table 3). The effect of different blades were not significant on SI however it was noted that the S and L-shaped blades had maximum and minimum SI values, respectively. The effects of different types of blades were not significant on II however it was noted that L-shaped and the straight blade (S) had maximum and minimum values of II respectively. Aggregate size distribution (ASD_8) could also be expressed as the percentage of aggregates greater than 2 to 8 mm. The results also showed that types of blades had no effect on ASD_8, however it was observed that the C-shaped and straight type blades had highest and lowest ASD_8 respectively.

Another factor for aggregate size distribution (ASD_{100}) can also be expressed as the percentage of aggregates greater than 2 to 100 mm while mean weight diameter (MWD_{d100}) can also be expressed as the diameter of particle size (dry basis) greater than 2 to 100 mm. Statistical analysis indicate that there were no significant differences between three types of blades and MWD_{d100}. However, the C-shaped blade had greater effect on MWD_{d100} compared to the other two blade types (straight and L-shaped). Rotational speeds of blade had significant effects on physical characteristics of soil. The mean weight diameter dry basis, MWD_d, showed high significant difference ($p < 1\%$) at 130 rpm when compared to the other two speeds. This was considered to be due to clod breaking and loosening of soil surface layer at the lowest speed (130 rpm). The results for mean weight diameter wet basis, MWD_w, proved that the difference was highly significant between the blade rotational speeds. Results revealed that rotary blade speeds had significant effects on instability index (II) and stability index (SI). This may be due to the fact that the rotary blade hit the soil surface with sufficient cutting velocity to produce particle size of soil and II. The highest II was obtained from lowest rotary speed. The result showed that a blade speed of 135 rpm had maximum effect in increasing ASD_8 to 62.714%. It means that lower rotary blade speed would produce higher value of ASD_8. Results obtained also showed that rotary blade at 130 rpm speed had 24.559 mm MWD_{d100}. This indicates that rotary blade speed had high significant effect on MWD_{d100}. This proves that slow hitting soil process by the rotary blade produces larger diameter clods.

From statistical method, the analysis of variance was done to check the significance of interrelationships among obtained data set. Interaction effects of rotary speeds × type of blades revealed significant effects on

Table 2. Analysis of variance (ANOVA) of different factors for traits measured.

S.O.V	DF	MWDd8 (mm)	MWDw (mm)	II	SI	2-8mm (ASD)	MWDd100 (mm)
Blade	2	3.06^{ns}	0.14^{ns}	1.82^{ns}	1.49^{ns}	2.86^{ns}	3.14^{ns}
Speed	2	17.00**	3.87*	19.32**	2.16^{ns}	6.48**	1.41^{ns}
block	2	18.00**	72.98**	92.76**	5.97^{ns}	16.44**	6.05*
Blade × Speed	4	4.3*	0.29^{ns}	1.71^{ns}	1.39^{ns}	4.78**	3.87*

** Significant at 1% level, * Significant at 5% level, ns- not significant, MWD_{d8} - dry mean weight diameter, MWD_{w} - wet mean weight diameter, SI - stability index, IS - instability index, MWD_{d100} - dry mean weight diameter between 0 to 100 mm, ASD - aggregate size distribution.

Table 3. Mean values and comparison of mean for traits measured.

Treatment		MWD_{d8} (mm)	MWD_{w} (mm)	II	SI	2 to 8 mm [ASD (%)]	0 to 100 mm (MWD_{d100})
Blade	S	3.20629^{a}	1.6262^{a}	1.5801^{a}	1.3475^{a}	58.456^{a}	24.751^{a}
	C	3.35139^{a}	1.5940^{a}	1.7574^{a}	0.8979^{a}	61.356^{a}	24.609^{ab}
	L	3.35242^{a}	1.5581^{a}	1.7943^{a}	0.8414^{a}	61.221^{a}	22.007^{b}
Speed	130	3.51080^{a}	1.3916^{B}	2.1192^{a}	0.7896^{a}	62.714^{a}	24.559^{a}
	147	3.28322^{b}	1.7280^{a}	1.3881^{b}	1.4093^{a}	57.799^{b}	24.197^{a}
	165	3.11609^{c}	1.6587^{ab}	1.6245^{b}	0.8880^{a}	60.521^{ab}	22.612^{a}

Means between treatments followed by similar letters do not differ significantly ($p>0.05$).

ASD_8 ($p<0.01$), MWD_{d8} and MWD_{d100} ($p<5\%$). These results showed that speed of rotary blades and types of blades were not independent. The rotary speed could have some effects depending on the type of blades used.

Conclusion

A new machine "comboplough" has been designed and developed for combined operations of primary and secondary tillage operations in a single pass. Field experiments were conducted at the Universiti Putra Malaysia Research Park, Serdang, Selangor having sandy clay loam soil texture. The results obtained indicated that no significant differences were noted between types of blades. The blade rotational speeds had high significant effects on selected parameters (MWD_d, MWD_w, II, SI ASD_d and MWD_{d100}). The effects of blade type were similar on MWD_d, MWD_w, II, SI ASD_d and MWD_{d100}. The results on MWD_d, II and ASD suggests that a rotary blade speed of 130 rpm was highly effective than 147 and 165 rpm.

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Full Length Research Paper

Evaluation of light extinction coefficient, radiation use efficiency and grain yield of soybean genotypes

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This experiment was performed at the Research Center of Agriculture and Natural Resources, Ardabil, province (Moghan), Iran, in 2009 and 2010. Light extinction coefficient, radiation use efficiency, yield and yield components of 17 soybean genotypes were evaluated. Number of seed per plant was significantly affected by years. In both years, all traits among genotypes were significantly different. In both years, the highest number of seed per plant was obtained from Apollo genotype. Omaha and NE-3399 genotypes had the highest seed weight in the first and second years respectively, whereas L.83-570 genotype produced the lowest value for this trait in both years. The highest yield in the first year (351.3 and 349.8 g m^{-2}) were obtained from Apollo and Ks-4895 genotypes, respectively, while in the second year, Zane genotype produced the highest yield. In both years the lowest yield were derived from Rend and L.83-570 genotypes. The maximum (0.62 ± 0.084) and minimum (0.44 ± 0.034) value for coefficients of light extinction were obtained from Hsus-H116 and Apollo genotypes respectively. The highest radiation use efficiency (1.14 ± 0.134) was obtained from Darby, and the lowest (0.91 ± 0.152) from L.17 genotype. In general the Apollo genotype with respect to its low light extinction coefficient and high radiation use efficiency produced the highest grain yield.

Key words: Light extinction coefficient, radiation use efficiency, genotype, soybean.

INTRODUCTION

Grain yield in soybean is influenced by environmental factors in growing conditions during the grain filling period (Mathew et al., 2000). Dynamics of grain growth process are affected by reproductive stage duration and environmental factors, such as solar radiation and temperatures govern during this growth stage (Bastidas et al., 2008). Radiation use efficiency (RUE) as g MJ^{-1}, is defined as amount of dry matter produced per solar energy received (Sinclair and Muchow, 1999; Purcel et al., 2002; Soltani et al., 2006) and frequently, calculated by linear regression slope of biomass vs. cumulative radiation absorbed or absorbed photosynthetic active radiation (Akmal and Janssens, 2004). RUE levels varies according to plant species, climatic conditions, crop management, plant developmental stage, measuring method and plant components, so, the models must be changed and developed for the species and the environmental conditions (O'Connell et al., 2004). Pengelly et al. (1999) reported that the light extinction coefficient (LEC) and RUE in bean, faba bean, sesbania and soybean is very different. However, the larger amount of radiation is received by the early growth of soybean on account of higher leaf area index; the highest RUE was obtained by sesbania, bean, soybean, and faba

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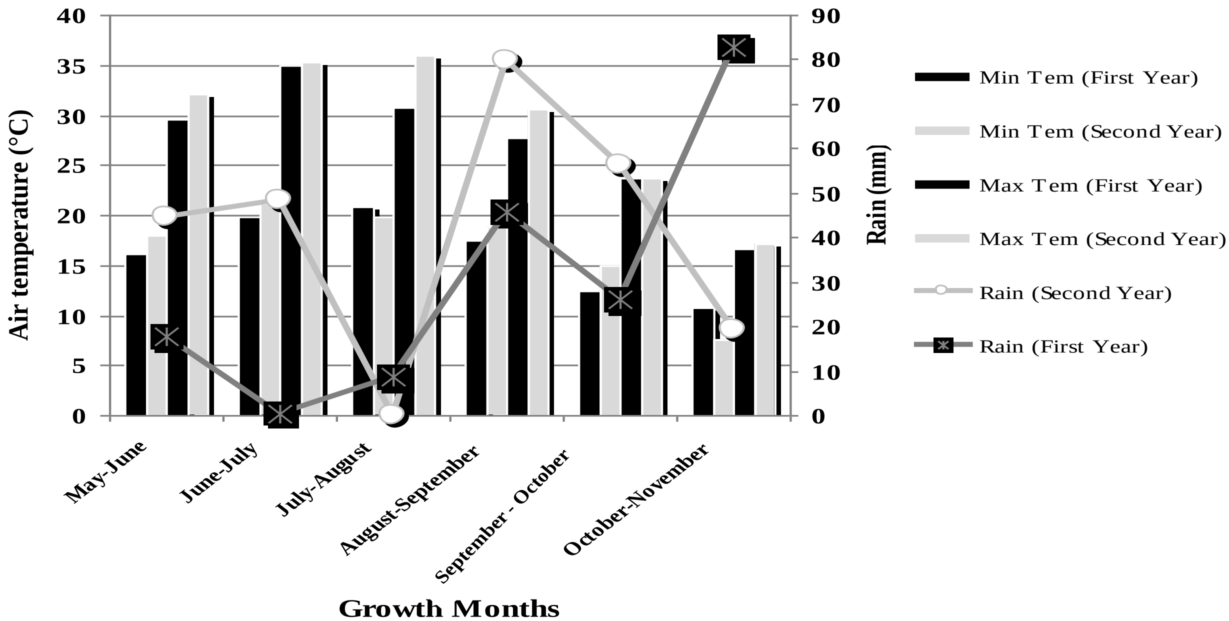

Figure 1. Local temperature and rainfall variance over the two years of experiment.

bean of 1.08, 0.94, 0.89 and 0.77 g MJ^{-1}, respectively. Also, LEC value for soybean, bean, sesbania,and faba bean was achieved 0.5, 0.59, 0.58 and 0.60, respectively. Alimadadi et al. (2006) found statistically significant difference for LEC and RUE among various cultivars of red beans and stated that with increasing leaf area index (LAI) and reduced LEC, RUE was increased in bean cultivars. Bell et al. (1993) showed that with increase in LEC from 0.3 to 1, RUE was decreased from 2.75 to 1.5 g MJ^{-1} in peanut. Also such results have been reported in C_4 plants (Kiniry et al., 1989). Ellis et al. (2000) calculated the amount of RUE for soybean isolines from 1.3 to 2.8 g MJ^{-1} and suggested that this can be attributed to higher RUE resulting from a more suitable arrangement of the leaves within the canopy and assigning the fewer photosynthetic matters to the reproductive parts. The lowest and highest amount of LEC in this work varied from 0.29 to 0.51 and the faster development of the leaf area coincided with the faster LEC. De Costa and Shanmugathasan (2002) reported the maximum RUE in soybean var. PB1 in about 0.92 to 0.98 g MJ^{-1} in full irrigation based on the absorbed photosynthetic active radiation (PAR), while in 0.45 PAR of the total radiation, maximum RUE of about 2.04 to 2.18 g MJ^{-1} was obtained. De Oliveira et al. (2009), obtained the RUE values in soybean of 1.46 to 1.99 g MJ^{-1} under the natural field conditions located in Brazilian Amazon region, based on the PAR in 2007 to 2008, respectively. In their opinion, the difference between the years was likely due to the water limitation in 2007 associated with the higher air temperature and pressure deficit. Liu et al. (2005) reported that the grain yield significantly varied in different soybean genotypes and found that the number of seeds and pods was higher in the high yielding ones. Liu et al. (2006) stated that the existing of the enough light in the flowering period increased yield of 144 to 252%, while, this increment varied from 32 to 115% in the pod stage. Soybean cropping, as second cultivation, is done in the Moghan region, which is associated with the reduced day length hours and incident radiation in the late season, so, it is necessary to evaluate different soybean genotypes and to introduce those having the higher yield and RUE.

MATERIALS AND METHODS

A field experiment was performed at the Research Center for Agriculture and Natural Resources, Ardabil province (Moghan), Iran, in 2009 and 2010. Moghan plain has warm and semi-dry Mediterranean climate. Average annual, maximal and minimal temperatures are 20.7, 14.7 and 8.6°C, respectively. Changes in temperature and precipitation of the region in the two years of the trial are shown in Figure 1. Soil type is calcareous thiosol, light brown to gray brown, with a depth of several meters in some areas. Soil pH is varied from 7.5 to 8.1 and the amount of electrical conductivity (EC) in the depth of a meter, reaches 1 m mho/cm. Experiment was conducted using 17 soybean genotypes (Table 1) in a randomized complete block design with three replications. Planting date was assigned on July first and third in the first and second tests, respectively. Each plot contained five rows, each four meters 45 cm apart and a total density of 20 plants per square meter was applied. After the seedbed preparation, seeds were inoculated with bacteria and immediately planted at a depth of 3 to 5 cm. Amount of the applied fertilizer was set according to the soil test results. Agricultural operations, including the amount and frequency of irrigation, were arranged based on the regional current standards.

Light extinction coefficient and radiation use efficiency

To determine the LEC, amount of the incident light above and under

Table 1. Soybean genotypes names used in this experiment.

No	Genotype
1	L.83-570
2	L.93-3312
3	NE3399
4	Darby
5	L.75-6141
6	Omaha
7	L.77-2061
8	Rend
9	Stress land
10	Ks4895
11	Spry
12	Hsus-H116
13	INA
14	Williams
15	L.17
16	Zane
17	Apollo

the canopy, and leaf area index (LAI), sun scanning device (Delta T, Cambridge England) was applied. Measurements were done in the three points of each plot in the mid-day through 11 am to 1 pm. Based on the measured values of LAI and radiation levels above and under the canopy, amount of the LEC (k) for all genotypes was determined using the Beer-Lambert equation (Sarmadnia, 1994):

$$\text{Ln } I_t/I_o = -k \times LAI$$

Where; I_t = amount of the light in the lower part of the canopy (MJ m^{-2} s^{-1}), I_0 = amount of the light in the upper part of the canopy (MJ $m^{-2}s^{-1}$), k = light extinction coefficient, LAI = leaf area index.

Slope of the linear relationship between LAI and the natural logarithm of the cumulative received radiation is considered as LEC. Recording the incident radiation and absorption by the canopy was performed five times to flowering stage and then, absorption amount of the radiation (F) was calculated according to Soltani et al. (2006):

$$F = 1- (I_1 / I_0)$$

Daylight hours, during the emergence to flowering stage of soybean genotypes (Prepared by the Meteorological Organization of the Ardabil province), were changed to the solar absorbed radiation (Doorenbos and Pruitt, 1977). Daily solar radiation values were calculated and collected as daily cumulative data by multiplying solar received radiation by the ratio of the received radiation per day. RUE (g MJ^{-1}) was calculated from the fitted linear relationship between the cumulative received radiation and the cumulative dry matter, the slope of this line represents the RUE (Sinclair and Muchow, 1999).
Plant height of three plants per plot was selected at the time of maturity and the average was calculated for a single plant. Number of seeds per plant, 100-seed weight and the grain yield per plant, were measured by harvesting from a square meter area of each plot.

Statistical analysis

The normality (uniformity) of data, were assigned by SPSS software. Data were subject to analysis of variance by SAS and graphs were drawn using Excel software.

RESULTS

Light extinction coefficient

In this experiment, the slope of the linear fit between LAI and cumulative radiation received by the natural logarithm to be served as LEC. The highest LEC (0.62) was observed in Hsus-H116 genotype (Figure 2) followed by genotypes Omaha, L.17 and L.83-3312 (Table 2). Also, the lowest K (0.44) belonged to the Apollo genotype (Figure 2).

Radiation use efficiency

Slope of the linear relationship between received cumulative radiation and the cumulative dry matter was considered as RUE. The highest RUE (1.14) was observed in genotype Darby (Figure 3) followed by the Omaha, Apollo and Ks-4895 genotypes, respectively (Table 2). Also, the lowest RUE (0.91) was obtained from L.17 genotype (Figure 3) and genotypes Rend, INA and L.83-570 with minor differences were placed before this genotype (Table 2).

Mean comparison of traits

Seed number per plant

Genotypes Apollo and Darby (with 99.9 and 96.4 seed per plant, respectively) were obtained as the maximum value of this trait in the first year, while the lowest number of seeds per plant (62.9) belonged to genotype Rend (Table 3). In the second year, the highest number of seeds per plant (108.5 and 107) belonged to the Apollo and Zane genotypes, and the lowest one, to the Rend, L.17 and INA at a rate of 76.9, 75.2, and 73.4, respectively (Table 3).

100-Seed weight

In the first year, the highest and lowest 100-seed weights were observed in Omaha (19.3 g) and L.83-570 (15.2 g) (Table 3). In the second year, the highest value for this trait (18.4 g) resulted from NE-3399 genotype, followed by genotype L.93-3312. In the second year, genotype L.83-570 possessed the lowest 100-seed weight (14.0 g) similar trend with first year (Table 3).

Seed yield

The highest seed yield (351.3 and 349.8 g m^{-2}) was obtained from Apollo and Ks-4895 genotypes in first year,

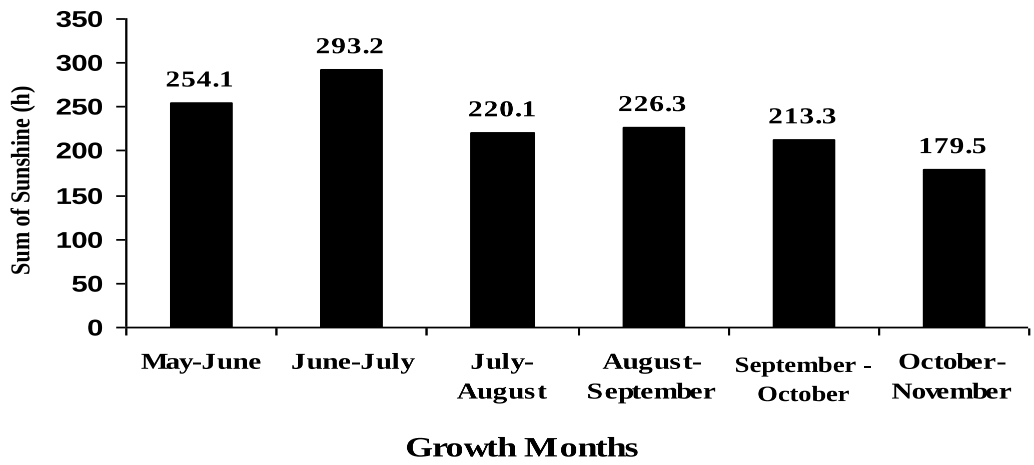

Figure 2. Sum of sunshine at growth season in first year of experiment.

Table 2. Radiation use efficiency (RUE g MJ^{-1}) (RUE ±SE) and extinction coefficients (k ±SE) with their corresponding R^2 and CV for soybean genotypes as a second crop.

Genotypes	Extinction coefficients (k)	R^2	CV (%)	RUE (g DM.MJ^{-1})	R^2	CV (%)
L.83-570	0.51±0.075	0.961	8.7	0.97±166	0.919	19.7
L.93-3312	0.59±0.017	0.997	2.3	1.01±0.139	0.946	16.1
NE3399	0.50±0.050	0.971	7.8	0.99±0.148	0.936	17.7
Darby	0.50±0.023	0.993	3.4	1.14±0.134	0.961	13.4
L.75-6141	0.49±0.027	0.991	4.3	1.01±0.139	0.947	16.0
Omaha	0.60±0.039	0.987	5.1	1.13±0.166	0.940	16.7
L.77-2061	0.51±0.123	0.849	17.6	0.99±0.132	0.949	15.2
Rend	0.54±0.134	0.843	18.5	0.94±0.148	0.931	18.4
Stress land	0.47±0.090	0.900	14.4	1.02±0.164	0.928	18.5
Ks4895	0.50±0.051	0.969	7.9	1.10±0.141	0.953	13.5
Spry	0.54±0.041	0.982	6.0	1.07±0.145	0.948	14.3
Hsus-H116	0.62±0.084	0.946	10.6	1.08±0.156	0.942	15.4
INA	0.56±0.087	0.931	11.9	0.96±0.167	0.917	20.4
Williams	0.45±0.034	0.982	5.9	1.04±0.173	0.923	19.7
L.17	0.59±0.044	0.983	5.9	0.91±0.152	0.923	19.3
Zane	0.53±0.034	0.988	4.9	1.03±0.191	0.907	20.8
Apollo	0.44±0.031	0.985	5.4	1.11±0.200	0.912	19.6

respectively. Also, genotypes L.83-570 (212.6 g m^{-2}) and Rend (207.0 g m^{-2}) showed the lowest rates (Table 3). In the second year, Zane genotype produced the highest grain yield (377.4 g m^{-2}), and Rend and L.83-570 genotypes showed the lowest yields (231.6 and 224.2 g m^{-2}), respectively (Table 3).

DISCUSSION

Light extinction coefficient

The highest and lowest LEC were obtained from Hsus-H116 (0.62) and Apollo (0.44) genotypes. Findings of Ellis et al. (2000) in soybean isolines illustrated that the lowest and highest LEC (0.29 and 0.51) was affected by faster leaf area development. Pengelly et al. (1999) reported the soybeans LEC about 0.50. Alimadadi et al. (2006) reported that there is significant difference among the varieties of red beans and vetch for the LEC and they showed reduction in LEC with increases of leaf area index. Ellis et al. (2000) believed that the differences for LEC between the various lines of soybean in the long term is a function of differences in canopy structure and in case of the vertical leaves in the upper parts and horizontal ones in the lower parts of the canopy, which provide

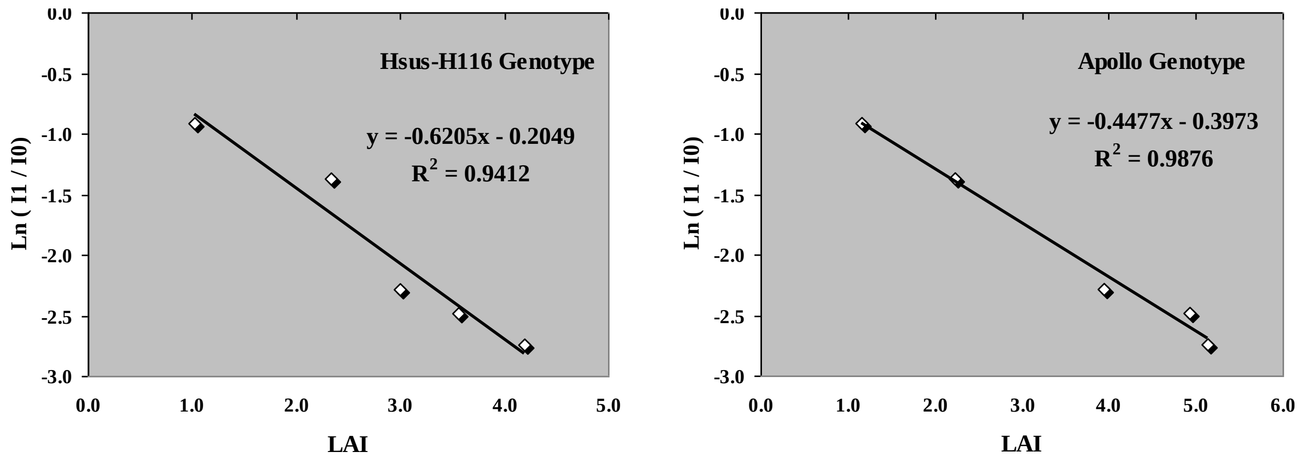

Figure 3. Relationship between natural logarithm (Ln I1/I0) and leaf area index (LAI) for anthesis of soybean genotypes with highest and lowest extinction coefficient (k) (Linear regression slope as light extinction coefficient (k)).

greater amount of light penetration into the canopy and the possibility of photosynthesis in the mid sections and lower parts (Keating and Carberry, 1993). Squire (1990) believes that the plants with the rapid canopy closure, has less LEC than those are slowly expanding. In this experiment, although Williams's genotype, having the highest leaf area index (5.4) and LEC, was almost equal to Apollo genotype, but had lower yield that it would be due to the low harvest index and assignment of photo assimilates into the parts more than grain.

Radiation use efficiency

The highest RUE was observed in Darby genotype, followed by the Omaha, Apollo and Ks-4895 genotypes, respectively (Figure 4). Also, the lowest RUE was seen in the L.17 genotypes. It was found that the plants such as corn and soybean, can only capture 50 to 60% of the photosynthetically active radiation (PAR) during the cropping season, that is merely up to 20 to 36% annually PAR (Della-Maggiora et al., 2000). It would be of great importance in lower RUE. On the other hand, Wheeler et al. (1993) believe that longer flowering period and indeterminate growth of some genotypes in long run, has impact on RUE changes which is due to differences in leaf area development and canopy structure (Ellis et al., 2000). Also, Akmal and Janssens (2004) expressed that the amount of RUE varies according to the plant species, weather conditions, crop management, plant developmental stage, measurement and herbal ingredients, and so, developed models must be applied for the same species and environmental conditions. RUE rate in soybean has been reported by Pengelly et al. (1999) up to 0.89 g MJ^{-1}. Alimadadi et al. (2006) reported significant difference in RUE between different cultivars of red bean and vetch and found that with increasing leaf area index and decreasing LEC, RUE was increased between varieties of beans. Bell et al. (1993) showed that with increasing LEC in peanuts from 0.3 to 1, the RUE was decreased from 2.75 to 1.5 g MJ^{-1}. Ellis et al. (2000) calculated RUE rates in soybean isolines from 1.3 to 2.8 g MJ^{-1} total radiation and expressed that the higher RUE is due to the higher and relatively long lasting LAI; the better distribution and arrangement of more leaves within the canopy, and less allocation of photo assimilates to the reproductive structures. De Costa and Shanmugathasan (2002) observed the maximum RUE soybean, PB1 var. in about 0.92 to 0.98 g MJ^{-1} based on the PAR under full irrigation circumstances and concluded assuming the ratio of PAR to total global radiation to be 0.45, the maximum RUE will be of about 2.04 to 2.18 g MJ^{-1} (APAR). De Oliveira et al. (2009) obtained the RUE values under the field conditions in Brazil's Amazon region, from 1.46 to 1.99 g MJ^{-1} PAR, in 2007 and 2008, respectively. They announced the possible reason for the differences as the water restrictions in 2007 along with the higher air temperature, vapor pressure deficit, and also increase in the global radiation into the earth during 2008. In our trial, genotypes with high yields were of high RUE, low LEC and high LAI. Despite its high RUE, the Omaha genotype lost grain yield, due to the high LEC and low LAI, but high rate of harvest index largely compensated for this loss.

Seed number per plant

In combined analysis, the impact of year) on the number of seed per plant was significant ($P<0.05$). Average of this trait in the first and second year was 82.5 and 93.2, respectively (Table 3). Number of seed per plant in genotypes showed significant increase in the second year than first year. Apollo genotype possessed the highest value in both years which showed a difference with the Rend genotype in the first year of 37.0 and with the INA genotype in the second year of 32.3%. Considering the

Table 3. Mean values of some traits in soybean genotypes over two years.

Traits / Genotypes	Mean values													
	Plant height (cm)		Pod plant^{-1}		Seed plant^{-1}		100-seed weight (g)		Seed yield		Harvest index (%)		LAI	
	2009	2010	2009	2010	2009	2010	2009	2010	2009	2010	2009	2010	2009	2010
L.83-570	66.2^{e}	74.8^{de}	31.9^{f}	38.9^{fg}	69.8^{gh}	79.9^{de}	15.2^{e}	14.0^{g}	212.5^{f}	224.2^{f}	28.9^{c}	29.0^{d}	4.5^{a-f}	4.8^{a}
L.93-3312	63.7^{e}	71.4^{e}	37.9^{f}	45.0^{e}	75.5^{d-g}	88.6^{cd}	18.7^{abc}	18.3^{ab}	282.6^{de}	323.2^{abc}	38.2^{ab}	39.2^{bc}	3.7^{f}	4.0^{a-f}
NE3399	77.8^{d}	88.2^{bc}	42.8^{e}	51.2^{c}	74.7^{efg}	92.5^{bc}	18.5^{abc}	18.4^{a}	276.8^{de}	340.4^{abc}	38.3^{ab}	39.4^{bc}	4.7^{a-e}	5.0^{f}
Darby	68.2^{e}	73.5^{de}	41.6^{cd}	50.5^{cd}	96.4^{a}	103.9^{ab}	17.6^{bcd}	16.4^{c-f}	338.9^{ab}	341.4^{abc}	41.7^{a}	45.6^{ab}	4.6^{a-f}	4.9^{a-e}
L.75-6141	66.7^{e}	71.2^{e}	49.7^{b}	58.4^{b}	91.1^{ab}	104.0^{ab}	16.5^{de}	16.0^{def}	301.1^{bcd}	334.4^{abc}	41.6^{a}	39.5^{bc}	4.9^{a-d}	5.2^{a-e}
Omaha	82.1^{bcd}	81.3^{cd}	45.3^{bc}	52.4^{c}	84.8^{bc}	98.6^{abc}	19.3^{a}	17.2^{a-e}	326.6^{abc}	339.1^{abc}	40.6^{a}	41.5^{b}	4.0^{def}	4.3^{a-d}
L.77-2061	101.3^{a}	101.3^{a}	56.2^{a}	58.7^{b}	86.7^{bc}	103.4^{ab}	16.6^{de}	15.7^{ef}	286.5^{cd}	325.9^{abc}	38.8^{ab}	40.5^{b}	4.7^{a-e}	4.9^{def}
Rend	88.0^{b}	88.2^{bc}	39.6^{de}	46.7^{de}	62.9^{h}	76.9^{e}	16.4^{de}	15.1^{fg}	207.0^{f}	231.6^{f}	28.4^{c}	28.1^{d}	4.1^{def}	4.4^{a-e}
Stress land	88.1^{b}	88.3^{bc}	38.6^{de}	45.2^{e}	79.8^{c-f}	89.2^{cd}	18.8^{abc}	17.2^{a-e}	300.9^{bcd}	306.5^{bcd}	39.4^{a}	39.3^{bc}	4.8^{a-e}	5.1^{a-e}
Ks4895	83.1^{bcd}	86.2^{bc}	32.1^{f}	39.8^{fg}	91.1^{ab}	98.8^{abc}	19.1^{ab}	16.7^{b-f}	349.7^{a}	331.8^{abc}	42.4^{a}	41.3^{b}	5.0^{abc}	5.3^{abc}
Spry	80.9^{cd}	84.2^{bc}	39.6^{de}	40.2^{f}	92.3^{ab}	97.5^{abc}	17.6^{cde}	16.7^{b-f}	325.1^{abc}	328.5^{abc}	40.9^{a}	40.7^{b}	4.8^{a-e}	5.1^{a-e}
Hsus-H116	87.3^{bc}	88.6^{bc}	31.9^{f}	36.2^{gh}	83.3^{b-}e	88.8^{cd}	18.2^{abc}	17.0^{a-e}	303.5^{bcd}	301.4^{cde}	37.4^{ab}	39.1^{bc}	4.2^{c-f}	4.5^{c-f}
INA	85.1^{bc}	90.7^{b}	26.3^{g}	32.3^{h}	68.7^{gh}	73.4^{e}	17.6^{bcd}	17.1^{a-e}	241.9^{ef}	250.8^{ef}	32.8^{bc}	31.2^{cd}	4.4^{b-f}	4.7^{b-f}
Williams	102.3^{a}	105.1^{a}	42.5^{cd}	50.6^{cd}	84.5^{bcd}	97.5^{abc}	17.5^{cd}	17.8^{abc}	295.6^{cd}	347.7^{abc}	38.1^{ab}	42.5^{b}	5.4^{a}	5.7^{a}
L.17	82.3^{bcd}	90.6^{b}	33.2^{f}	33.5^{h}	73.6^{fg}	75.2^{e}	18.8^{abc}	17.7^{a-d}	277.6^{de}	265.5d^{ef}	38.5^{ab}	38.3^{bc}	3.9^{ef}	4.2^{ef}
Zane	80.4^{cd}	91.9^{b}	54.4^{a}	64.9^{a}	87.1^{bc}	107.0^{a}	17.7^{a-d}	17.5^{a-d}	308.6^{bcd}	377.4^{a}	40.5^{a}	46.4^{ab}	4.2^{c-f}	4.5^{c-f}
Apollo	88.3^{b}	86.0^{bc}	48.6^{b}	59.6^{b}	99.9^{a}	108.5^{a}	17.6^{bcd}	16.5^{a-d}	351.2^{a}	358.9^{ab}	42.7^{a}	52.0^{a}	5.1^{ab}	5.4^{ab}
Mean	81.9	86.0	40.8	47.3	82.5	93.2	17.8	16.8	293.3	313.5	38.2	39.6	4.5	4.8

Data with the same letter have no significant difference to each other at ($P<0.05$) probability level.

existence of significant positive correlation (0.871 and 0.861) between this trait and grain yield in the first and second years (Table 4), increased grain yield can be achieved by its improvement and genotypes with a greater number of seeds are expected to have a higher grain yield. Liu et al. (2005) indicated the role of seed number per plant in the final grain yield.

100-seed weight

100-seed weight was not influenced by year, but differences between genotypes within two years were significant (Table 3). With increasing seed number per plant in the second year, 100-seed weight partially was declined. As we know, in the process of seed filling, not only the environmental conditions such as sufficient moisture is involved in the transfer process, but also current enough photosynthesis, reserved substances and balance in the source and sink relations have great importance. Increase in the sink values without providing sufficient sources, may result in their inadequate and undesirable evolution and development. Omaha and NE-3399 genotypes obtained the highest seed weight in the first and second year, respectively. Higher amounts of this trait led to the favorable yields in these genotypes. In contrast, L.83-570 genotype that had lowest 100-seed weight during both years was found to be very low yielding within both years (Table 3). Positive and significant correlations (0.540 and 0.606) between the 100-seed weight and grain yield in first and second year (Table 4) show that with providing suitable conditions for enhancing 100-seed weight, final grain yield can be improved. Bangar et al. (2003) found that there is significant and positive correlation between 100-seed weight and grain yield in soybean genotypes, which is in accordance with our findings. Similar results was confirmed by Arashad

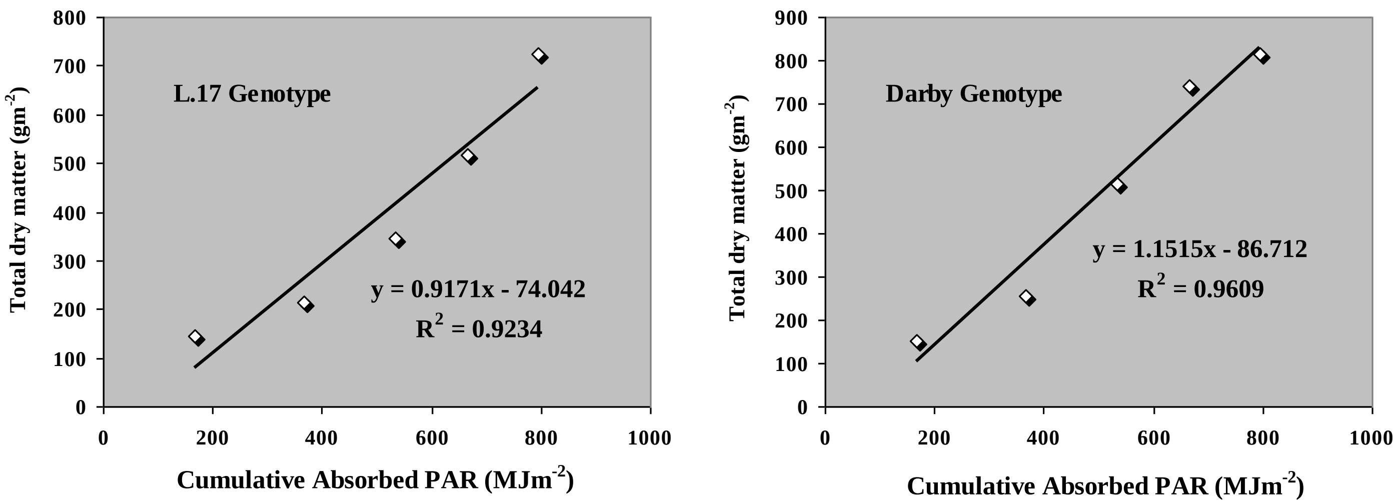

Figure 4. Relationship between dry matter accumulation and cumulative absorbed PAR for soybean genotypes with highest and lowest radiation use efficiency (RUE) (Linear regression slope as radiation use efficiency (MJm^{-2}).

Table 4. Correlation coefficients among measured traits in soybean genotypes over the two years.

Traits	Year	Plant height	Pod plant^{-1}	Seed plant	100-seed weights	Seed yield	Harvest index	LAI
Plant height	2009	1						
	2010	1						
Pod plant^{-1}	2009	0.184^{ns}	1					
	2010	0.055^{ns}	1					
Seed plant^{-1}	2009	0.040^{ns}	0.454**	1				
	2010	-0.040^{ns}	0.742**	1				
100-seed weights	2009	0.037^{ns}	-0.152^{ns}	0.063^{ns}	1			
	2010	0.081^{ns}	0.026^{ns}	0.123^{ns}	1			
Seed yield	2009	0.052^{ns}	0.291*	0.871**	0.540**	1		
	2010	0.010^{ns}	0.607**	0.861**	0.606**	1		
Harvest index	2009	0.010^{ns}	0.360*	0.806**	0.475**	0.909**	1	
	2010	0.033^{ns}	0.467**	0.739**	0.523**	0.859**	1	
Leaf area index	2009	0.199^{ns}	0.106^{ns}	0.410**	-0.094^{ns}	0.305*	0.307*	1
	2010	0.127^{ns}	0.196^{ns}	0.378*	-0.026^{ns}	0.288*	0.187^{ns}	1

ns, *,** non-significant and significant at P<0.05 and P<0.01, probability levels, respectively.

et al. (2006).

Seed yield

Seed yield was not affected by year, although in the second year its average increased compared with the first year at a rate of 6.4%, which was mainly related to the increases in number of seed per plant, because 100-seed weight was reduced this year (Table 3). Mathew et al. (2000) showed that growth conditions have profound effect on yield during grain filling period. In the environmental conditions without biotic and abiotic stresses, climatic factors such as light and temperature have the most impact on the yield, which was confirmed by Jeyaraman et al. (1990) finding, whom concluded that the production potential of the soybean plant can be improved when the maximal and minimal temperatures ranges from 31.2 to 31.6 and 20.4 to 20.9°C, respectively. Statistically significant differences in yield among the genotypes within two years of our experiment, indicated variability and genetic diversity among the populations and these genotypes are suitable for selection. Liu et al. (2008) stated that the continuous increases in soybean yield in North China during the last half century, especially in recent years, mainly resulted from increase in unit area and different factors including favorable tillage, plant density, LAI and its durability, increases in plant photosynthesis, sink-source relations, seed development regulators, stress physiology, cultivar selection, and also, plant protection. Traits related to the seed yield have major role in determining the final grain production. In this experiment, the highest seed yields in the first and second years were achieved from the Apollo and Zane genotypes, respectively. In general these genotypes had the greatest number of pods and seeds per plant (over the two years) among all of the investigated genotypes, and L.83-570 and Rend genotypes produced the lowest yield within two years. Also L.83-570 genotype had the lowest seed weight (at two years) and Rend genotype produced the lowest number of seed per plant (two years) among genotypes (Table 3).

Conclusion

It was found that there is high genetic diversity among the genotypes used in this trial. Among the traits related to yield, harvest index and the number of seed per plant showed the highest correlation with the grain yield. It was cleared that in the genotypes with high LAI, LEC was decreased and the amount of RUE was increased and this led to the seed yield increment.

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Financial and income approach analysis in micro (MEs) and small / medium sized enterprises (SMEs): A comparative approach in fruit and vegetables processing industry in Italy

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The aim of the research is to evaluate the differences between economic and financial results in a sample of micro enterprises (MEs) and small / medium sized enterprises (SMEs) in fruit and vegetables processing industry in Italy. The firms included in the sample operate in an industry characterized by high capital intensity; this character is caused by the length of working capital cycle and high level of fixed asset investment. These characteristics of the firms can amplify the differences in economic and financial management results. In order to offer a comparison in applying economic and financial approaches, especially useful for agro-food firms operating in a capital intensive sector, in the article are calculated 12 ratios, of which 7 are sustainability ratios (calculated 3 with economic approach and 4 with financial approach) and 5 are interest coverage ratios (calculated 2 with economic approach and 3 with financial approach). The article highlights that economic and financial approach has statistically different result in the firm's sample. Considering the significant differences in economic approach and financial approach, the firms could incur in error, and it will be necessary to identify which of the 2 approaches provides the correct indication of sustainability. The way of analysis proposed in the article can then be used to analyze firms operating in other agro-food sectors, especially if characterized by high capital intensity, high capital investment in fixed assets, long production cycle and long time debt collection.

Key words: Firm cycle sustainability, economic and financial approach, interest coverage ratio, fruit and vegetables processing industry.

INTRODUCTION

The evaluation of an investment has the aim to quantify the return on equity capital (Lagerkvist and Andersson, 1996). The return on capital has to be not only positive, in terms of profit and even in terms of intermediate income margins, but also higher than the opportunity cost of capital invested, considering the return on alternative investments, given the risk (Damodaran, 1994; Francis et al. 2004; Lettau and Ludvigson 2005). The evaluation of these conditions could be verified considering economic or financial approaches; the first approach compares

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revenues and costs applying the accrual approach, taking into account the value creation, as expressed by accounting data, in order to quantify profit. The second approach considers the cash inflow and outflow, calculated on a cash basis, to express the cash flow available to manage the firms and available for equity holders, to be paid as dividends. The economic and the financial approach may have different results, as expressed by several researchers (Bowen and Owen, 1986; Dechow 1994; Iotti and Bonazzi, 2012). Income margins, such as EBITDA, EBIT and PROFIT, even applied in cover ratio covenants (Dothan, 2006; Gray et al., 2006), do not directly express the liquidity generated by firm management; it could be possible to have situations of unsustainable financial cycle, even when the accrual results are positive. In these cases, the firm could suffer a default situation for non-financial sustainability of the management cycle as expressed in several studies about fixed asset cycle (Fazzari and Petersen, 1993; Cleary, 1999; De Miguel and Pindado, 2001) and working capital cycle (Howorth and Westhead, 2003; Padachi, 2006; Taylor, 2011). The usefulness to compare economic and financial approach is a central topic especially in the management of micro enterprises (MEs) and small and medium sized enterprises (SMEs); in these companies, an error in the assessment of business cycle sustainability can cause default because these firms normally have an access to bank loans and equity market worst than large companies. For this purpose, the article analyzes the economic and financial results in a sample of MEs and SMEs operating in the processing industry of fruit and vegetables in Italy. Fruit and vegetables processing firms are characterized by high capital absorption in the cycle of fixed assets and in the working capital cycle; this is due to processing of raw fruit and vegetables that often requires high investments in plant and machinery and also determines the absorption of capital, particularly caused by long time collection of accounts receivable. Capital requirements primarily determines an increasing in sources of capital (equity or debt), potentially leading to increase borrowing costs, and also determines a time lag between the economic cycle and financial cycle, so the sector appears interesting in applying a survey about economic and financial approaches to firm’s cycle sustainability. Moreover, the high capital requirements level is also caused by the slow accounts receivable turnovers caused by sales that firms often do to large companies. The firms of the sector, in fact, are generally characterized by market difficulties; the great distribution firms (large retailers), purchasing large volumes of production, are often able to influence the market price of the finished product. The sales to large retailer firms leads to a dilation of the times of collection of accounts receivable with negative effects on the financial sustainability of the business cycle; long delay in credit payments by retailers often causes an increasing in working capital requirements. The problem of absorption of working capital management is a central theme for the majority of businesses in the fruit and vegetables processing industry in the Mediterranean basin, both for companies in Europe (Spain, France, Italy, Greece, Turkey) and for African firms (Morocco, Algeria, Tunisia, Libya, Egypt). Therefore, it is necessary to make an assessment of sustainability of the cycle of working capital verifying the differences between PROFIT and cash flow in firm's sample data. In the article, the aim is to assess whether there are statistically significant differences in economic and financial results of firms in the sample; these results are expressed in terms of economic margins (EBITDA, EBIT and PROFIT), and in terms of financial results as cash flow (CF), operating cash flow (OCF), unlevered free cash flow (UFCF) and free cash flow to equity (FCFE). In the article we also consider coverage ratios calculated considering a traditional approach (economic approach), even suggesting an innovative approach (financial approach), as exposed in the methodological section of the article. In fact, in case of significant differences in economic approach and financial approach, the firm using only 1 of 2 approaches to evaluate could incur in error, and it will be necessary to identify which of the 2 approaches provides the correct indication of sustainability. The article is organized as follows: First it exposed the methodology applied to analyze the principles considered for economic and financial approaches, with a review of the literature having the aim to express the role of economic and financial analysis to evaluate the firm’s cycle sustainability. It is then presented the sample of firms and its characteristics in terms of economic and financial data; moreover we verify if there was a significant difference between economic and financial results in the firm data. The analysis is developed as follows:

1. Calculation of sustainability ratios according to financial and economic approach; these ratios compare income and financial margins to total assets invested, for each firm; for these ratios, the results are compared between MEs and SMEs.
2. Calculation of interest coverage ratios (ICRs) according to economic and financial approach; these ratios compare income and financial margins with the cost of debt in the sample for each firm and the results are compared between MEs and SMEs.

The conclusions of the work, the limits of the analysis and the possible development of future research are then presented at the end of the article.

LITERATURE REVIEW

The differences in firm’s results, applying economic or financial approaches, could be caused by lags between economic and financial cycle, as several studies have shown (Grenberg et al., 1986; Kwon, 1989; Dechow, 1994; Dechow and Dichev, 2002; Russell, 2009; Iotti and Bonazzi, 2013). This situation occurs particularly in firms in which we note high levels of capital absorption (Glancey, 1998; Kieschnick et al., 2008; Bonazzi et al., 2012) or, as in MEs and SMEs, that have limited access to equity and debt capital market and present default rates higher than large companies (Grablowsky, 1976; Dunn and Cheatham, 1993; Peel and Wilson, 1996; Molina and Preeve, 2009). The manager that use only one of these two approaches to evaluate firm's cycle sustainability incur in error, and it could be necessary to identify which approach provides the correct indication of sustainability. The Financial Accounting Standards Board (FASB) (1978) indicates in the "Objectives of Financial Reporting by Business Enterprises", issue, SFAC 1st, that the fundamental purpose of accounting information, considering an accrual approach, is to predict future cash flows. In fact, equity holders evaluate their advantage considering PROFIT distribution as dividends, so future cash flows are essential to assess the firm's capacity to share dividends. The information based on a cash flows approach has its practical applications considering the limits of a traditional accounting system that is based on the principles of historical cost and accrual basis value analysis. The importance to analyze operating cash flows, in comparison with accounting values, is exposed by several studies; between these it is conducted the forecast of stock exchange value analysis by Rayburn (1986), Wilson (1986, 1987), Sloan (1996), Wang and Eichenseher (1998), Charitou and Panagitodes (1999), Finger (1994), Hussain and Al Attar (2003); these studies consider the firms capacity to generate future cash flow in comparison with accrual results. Due the importance of information based on operating financial cycle to assess the firm's sustainability, many researchers were involved to verify the FASB's assertion expressing that the last earnings could provide a better base to estimate future operating cash flow than last cash flows. This assertion was criticized by Finger (1994), Krishnan and Largay (2000), Al-Attar and Hussain (2008) but was confirmed by other researchers such as Rayburn (1986), Murdoch and Krause (1989, 1990). Moreover, during time, it is possible to note a changing in the definition of cash flow applied, even varying among researchers; a first definition express cash flow as the account result (PROFIT or EBITDA) plus depreciations and amortizations, as in Beaver et al. (1966), Ball and Browen (1968); other researchers, as Gombola et al. (1987), start to express cash flow considering working capital liquidity absorption of cash as variations in accounts payable and accounts receivable, inventories and other voices of working capital; this field of research was followed by Wilson (1986, 1987), Rayburn (1986), Finger (1994), Lorek and Willinger (1996), Boisjoly (2009). Others as Livnat and Zarowin (1990), Dechow et al. (1988), consider the SFAS n. 95 (Statements of Financial Accounting Standards) issue to quantify operating cash-flow.

MATERIALS AND METHODS

The evaluation of firm's cycle sustainability is issued applying ratios and margins. The ratios express relative quantities as relationships between values. These values can be economic or financial, depending on the type of approach applied. Economic ratios assess the sustainability considering economic values as numerator of the ratios like earnings before interest, tax, depreciation and amortization (EBITDA) or earnings before interest and tax (EBIT). These ratios are able to give an approximate evaluation of sustainability of the business cycle, correlating income margin values, as numerator, with values that express debt or debt service in the denominator. The numerator values are, in fact, intermediate income margins calculated according to accrual approach then only approximating cash flow availability. The article tries to assess the financial sustainability even considering financial values as numerator of the ratios: Cash flow (CF), operating cash flow (OCF), unlevered free cash flow (UFCF), and free cash flow to equity (FCFE). These ratios are useful to assess the sustainability of the business cycle comparing financial values (numerator) with values expressing debt or debt service (denominator).

Ratios analysis with economic approach

To evaluate the firm's performance, an accounting base of values generally accepted is the annual account of the company; this accounting document quantifies economic and financial firm's performance and consists of income statement and balance sheet. Income statement quantifies the annual profit available for equity holders, with regard to positive and negative voices of income, on an accrual basis (accounting methods). The profit analysis is a value based approach that does not consider cash inflow or outflow. Considering an economic (income) approach, in the article are applied the following ratios to express the firm's capacity to generate income:

$$S_1 = \mathrm{EBITDA} / \mathrm{TA} \;\; ; \;\; S_2 = \mathrm{EBIT} / \mathrm{TA} \;\; ; \;\; S_3 = \Pi / \mathrm{TA} \tag{1}$$

Where EBITDA is earning before interest, tax, depreciation and amortization, EBIT is earning before interest and tax, Π is PROFIT, TA is total asset. To calculate S_1, S_2 and S_3, we quantify the value of production (VP), for a generic time t, as:

$$\sum_{i=1}^{I} p_{t,i} q_{t,i} + \left(\sum_{f=1}^{F} I_{t,f} v_{t,f} - \sum_{g=1}^{G} I_{t-1,g} v_{t-1,g}\right) = S_t + (I_t - I_{t-1}) = S_t + \Delta I_{t,t-1} = VP_t \tag{2}$$

In (2), $p_{t,i}$ is price per unit, at time t, of goods and services sold in number that is $I : I \geq 1$, q_t is quantity sold, $I_{t,f}$ and $I_{t-1,f}$ are inventories, in number $F : F \geq 1$ and $G : G \geq 1$, respectively at time t e t-1. These good are valued at their respective value per unit that is v; S_t is total sales at time t, then $\Delta I_{t,t-1}$ expresses the variation in inventories value between time t-1 and time t. We have that inventories in income statement and in balance sheet are equal so it is that $I_t = WCi_t^a$ and $I_{t-1} = WCi_{t-1}^a$, where WCi^a is working capital inventories asset, at a given time (t-1 and t respectively). The value of production (VP) is a flow value (Dechow and Dichev, 2002) namely a value that is in formation during a period, in this case t, without considering value assumed during time $T \in [t-1,t]$. Operative costs in a given time t are:

$$M_t = \sum_{m=1}^{M} m_{t,m} q_{t,m} \;\; ; \;\; S_t = \sum_{s=1}^{S} s_{t,s} q_{t,s} \;\; ; \;\; R_t = \sum_{r=1}^{R} r_{t,r} q_{t,r} \;\; ; \;\; L_t = \sum_{l=1}^{L} l_{t,l} q_{t,l} \;\; ; \;\; O_t = \sum_{o=1}^{O} o_{t,o} q_{t,o} \qquad (3)$$

Where M_t are cost for raw materials, S_t cost for services, R_t cost for rent and leasing, L_t labor cost, O_t other operative cost. In (3) $m_{t,m}$, $s_{t,s}$, $r_{t,r}$, $l_{t,l}$, $o_{t,o}$, express, for a given time t, the single voices of costs, so we have $M : M \geq 1$, $S : S \geq 1$, $R : R \geq 1$, $L : L \geq 1$, $O : O \geq 1$ with their respective quantity $q_{t,m}$, $q_{t,s}$, $q_{t,r}$, $q_{t,l}$, $q_{t,o}$. The operative, cost without financial effect, are:

$$D_t = \sum_{d=1}^{D} d_{t,d} q_{t,d} \;\; ; \;\; A_t = \sum_{a=1}^{A} a_{t,a} q_{t,a} \qquad (4)$$

Where D_t are amortizations of fixed assets (FA_t), A_t are depreciation. In (4) $d_{t,d}$ and $a_{t,a}$ are the cost per unit, at time t, of amortizations and depreciation; these cost are respectively in number that is $D : D \geq 1$ e $A : A \geq 1$. The respective quantity are $q_{t,d}$ and $q_{t,a}$. The net financial income is:

$$SF_t = I_t^a - I_t^p + (I_t^{ac} - I_t^{pc}) \qquad (5)$$

Where I_t^a are interest income at time t, I_t^p are interest expense at time t, $(I_t^{ac} - I_t^{pc})$ is balance of revenues and costs deriving from currency exchange rate. The income deriving from extraordinary operations (SX_t), at time t, is:

$$SX_t = X_t^a - X_t^p \qquad (6)$$

In (6) X_t^a are extraordinary income and X_t^p are extraordinary expense. The balance of the management revaluations and devaluation of financial assets is given, at time t, as:

$$SZ_t = Z_t^a - Z_t^p \qquad (7)$$

In (7) Z_t^a are revaluations of financial activities, Z_t^p devaluation of financial activities. Hence, at time t, it is:

$$VP_t - (M_t + S_t + R_t + L_t + O_t) = EBITDA_t \;\; ; \;\; EBITDA_t - (D_t + A_t) = EBIT_t \;\; ; \qquad (8)$$
$$EBIT_t + SF_t + SX_t + SZ_t = \Pi_t^{aT}$$

In Equation (8) EBITDA approximates the creation of liquidity, net of non-monetary costs ($D_t + A_t$), while it has not this capacity about the value of production, considering monetary (S_t) and non monetary values ($\Delta I_{t,t-1}$); EBIT is an income margin that express operative income; Π_t^{aT} is profit before taxes and profit after taxes is given (Π_t^{pT}) as:

$$\Pi_t^{aT} - T_t^Y = \Pi_t^{pT} \qquad (9)$$

In Equation (9) Π_t^{pT} (PROFIT) expresses the firm's capacity to remunerate, at time t, the equity capital; T_t^Y are income taxes.

Ratios analysis with financial approach

In the annual account, the balance sheet expresses investment and source of capital; in a given period t, we can express balance sheet as follows:

$$FA_t + WCi_t^a + WCar_t^a + WCo_t^a + L_t = E_t^c + E_t^s + \Pi_t^{pT} + \qquad (10)$$
$$+ WCap_t^s + WCo_t^s + DF_t^{M<12} + DF_t^{M>12}$$

In Equation (10), first member, the investments are given by FA as fixed assets, WCi^a as working capital inventories, $WCar^a$ as working capital accounts receivable, WCo^i as other voices of investment in working capital, L is financial liquidity. In equation (10), second member, the sources of capital are given by E^c that is share capital, E^s is reserves, Π^{pT} is PROFIT after taxes, $WCap^s$ is working capital accounts payable, WCo^s is other voices of capital source in working capital, $DF^{M<12}$ are financial debts expiring within 12 months and $DF^{M>12}$ are financial debts expiring over 12 months; considering that is $E_t^c + E_t^s + \Pi_t^{pT} = E_t^T$ where E_t^T is equity, we can also express (10) as follows:

$$TA_t = E_t^T + D_t^T \qquad (11)$$

The first member of (11) represents capital invested in the firm at time (TA), as total asset t, the second member represents source of capital as the sum of equity (E^T) and debt (D^T), and we can express as follows: $E^T + D^T = TS$, where TS is total source of capital. The net investment in working capital (NWC), as net working capital, expresses the absorption of financial resources as a result of the cycle of buying, processing and selling products, as follows:

$$(WCi_t^a + WCar_t^a + WCo_t^a) - (WCap_t^s + WCo_t^s) = WC_t^{aT} - WC_t^{sT} = NWC_t \qquad (12)$$

In Equation (12) WC^{aT} is investment in working capital (active), WC^{sT} is source of working capital (passive), NWC is net working capital, expressing the amount of net resources generated (NWC < 0) or absorbed (NWC > 0) by working capital cycle (Love et al., 2007). NWC > 0 expresses a "working capital conservative policy" (Weinraub and Visscher, 1998). Several studies (Kargar and Blumenthal, 1994; Hill et al., 2010) express that $| WC^{aT} > WC^{sT} | \Rightarrow NWC > 0$. A policy in which NWC < 0 is called "aggressive management of working capital" (Grablowsky, 1984; Weinraub and Visscher, 1998), this situation is considered risky, as it has been shown (Hill et al., 2010) that NWC > 0 is inversely related to risk of default. If NWC > 0 we can express (1) as follows:

$$FA_t + NWC_t + L_t = E_t^T + DF_t^{M<12} + DF_t^{M>12} \qquad (13)$$

To analyze the cycle of cash flow creation, we have to consider the financial statement that is the table applied to quantify cash flow generated in firm's management; to prepare the financial statements are applied (Wallace et al., 1997; Francis and Schier, 1999) two approaches. The direct method (Dechow and Dichev, 2002; Chittenden et al., 1998; Almeida et al., 2004) considers the revenues and costs as determinants of cash flow (CF) only if they have a financial impact; otherwise the indirect method (depth in studies of Carroll and Griffith, 2001) quantifies the net cash amount generated by firm's management starting the analysis from an income margin (generally EBIT or PROFIT). Researchers have long discussed on which is the better method to express cash flows, as exposed in Krishnan and Largay (2000). In this article, according to the most part of the available data for the firm's sample, we apply the indirect method, that is:

$$\Pi_t^{pT} + (D_t + A_t) - (I_t^a - I_t^p) = CF_t \;\; ;$$
$$CF_t - (WCi_t^a - WCi_{t-1}^a) - (WCar_t^a - WCar_{t-1}^a) - (WCo_t^a - WCo_{t-1}^a) + (WCap_t^s - WCap_{t-1}^s) +$$
$$+ (WCo_t^s - WCo_{t-1}^s) = OCF_t \;\; ;$$
$$OCF_t - (FA_t - FA_{t-1}) - (D_t + A_t) = UFCF_t \;\; ;$$
$$UFCF_t + (I_t^a - I_t^p) = FCFE_t \qquad (14)$$

In (14), at time t, Π^{pT} is PROFIT after taxes, D is depreciation, A is amortization, I^a is interest income, I^p is interest charge, CF is cash flow, OCF is operating cash flow, UFCF is unlevered free cash flow, FCFE is free cash flow to equity. Various researchers (Beaver, 1966; Deakin, 1972; Sartoris, 1983; Kim et al., 1998) consider that, for a given time t, CF expresses self-financing potential capacity. To express OCF (Klammer and Reed, 1990; Kochanek and Norgaard, 1998; Deloof 2003) we calculate as follows:

$$\begin{aligned}&CF_t-(WCi_t^a-WCi_{t-1}^a)-(WCar_t^a-WCar_{t-1}^a)-(WCo_t^a-WCo_{t-1}^a)+(WCap_t^s-WCap_{t-1}^s)+\\&+(WCo_t^s-WCo_{t-1}^s)=CF_t-(WC_t^{aT}-WC_{t-1}^{aT})+(WC_t^{sT}-WC_{t-1}^{sT})=CF_t-(NWC_t-NWC_{t-1})=\\&=CF_t-\Delta NWC_{t,t-1}=OCF_t\end{aligned} \tag{15}$$

Where $\Delta NWC_{t,t-1}$ expresses the net working capital variation between time t-1 and time t. It is to note that $\Delta^+NWC_{t,t-1} \Rightarrow \Delta^-OCF_t$ so that an increase in net working capital involves an increase of liquidity absorption that reduces the amount of cash available (OCF); vice versa, in case of negative variation ($\Delta^-NWC_{t,t-1} \Rightarrow \Delta^+OCF_t$) we can note an increasing in OCF available. Even more, we have to consider that an increase in inventories is a positive voice of income but determines a reduction of financial liquidity (OCF) due to absorption of capital, and vice versa. Considering this relations, firms with positive profit, determined by an increase of inventories, record a reduction of self-financing capacity of opposite sign and equal absolute value: $\Delta^{\pm}(WCi_t^a-WCi_{t-1}^a) \Rightarrow \Delta^{\mp}OCF_{t,t-1}$ that is $|\Delta^{\pm}(WCi_t^a-WCi_{t-1}^a)|=|\Delta^{\mp}OCF_{t,t-1}|$. In this way, considering that OCF expresses the changes in cash resulting from the cycle of working capital; several researchers (Takahashi et al., 1984; Casey and Bartczak, 1985; Gombola et al., 1987, Charitou and Vafeas, 1997; Hill et al., 2010) consider OCF a more expressive liquidity margin because could express better free cash flow creation, considering net working capital absorption. Given OCF, and considering the absorption of liquidity due to investment, we can calculate unlevered free cash flow (UFCF) as follows: $[(FA_t - FA_{t-1}) - (D_t + A_t)] > 0 \Rightarrow \Delta^-UFCF_{t,t-1}$ and vice versa, where FA is investment fixed asset. UFCF is therefore the cash flow available, given the investments in fixed assets, at a time t, to remunerate financial debts and equity capital; this is done through the payment of interest expenses on financial debts (I^p) and the distribution of dividends to holders of equity capital. In a given period t, $FCFE_t$ represents the cash flow available for dividends distribution to equity holders and for the discretionary reduction of financial debt. In order to quantify the firm's capacity to create liquidity, in the article are then applied sustainability ratios with financial approach:

$$S_4=CF/TA\ ;\ S_5=OCF/TA\ ;\ S_6=UFCF/TA\ ;\ S_7=FCFE/TA \tag{16}$$

Interest coverage ratios (ICRs)

In the article are considered additional 5 ratios, numbered from S_8 to S_{12}, that express the ability of firms to pay interest on loans. These ratios are interest coverage ratios (ICRs) calculated considering economic and financial approach. According to economic approach, it is possible to express sustainability in terms of earnings before interest and taxes (EBIT) and / or in terms of earnings before interest, taxes, depreciation, and amortization (EBITDA); applying a financial approach, we can express the interest coverage ratios in terms of cash flow (CF) and / or operating cash flow (OCF) and / or unlevered free cash flow (UFCF); the importance of these ratio were expressed by several researchers, as in Leland (1994, 1998) where it is shown that an interest coverage ratio covenant could reduce asset volatility when covenants are costly to enforce. The covenants considered in bank loan agreements (Gray et al., 2006) are leverage and current ratio, moreover interest coverage ratios are also frequently used, expressing EBIT and / or EBITDA to interest expense ratio. Rarely ICRs are expressed considering OCF or UFCF as numerator, even if it could be a more correct way to calculate the ratio. For the purposes of calculating the sustainability of the management cycle, are often considered ratios that express the capacity of intermediate income margins to pay the cost of financial debt and repay principal; these ratios are qualified as ICR with economic approach and are expressed as follows:

$$S_8=EBITDA_t/I_t^p\ ;\ S_9=EBIT_t/I_t^p \tag{17}$$

S_8 (ICR_1) and S_9 (ICR_2) express firm's capacity to pay interest in a given time t with EBITDA and EBIT respectively, as income margins (Goldstein et al., 2001; Dothan, 2006). S_8 considers a more conservative approach to sustainability assessment because $(D_t + A_t) \geq 0 \Rightarrow EBITDA_t \geq EBIT_t \Rightarrow S_8 \geq S_9$. If $I_t^p = 0$ the ratio S_8 and S_9 calculus loses significance for the absence of cost of debt. In the work are even applied:

$$S_{10}=CF_t/I_t^p\ ;\ S_{11}=OCF_t/I_t^p\ ;\ S_{12}=UFCF_t/I_t^p \tag{18}$$

S_{10} (ICR_3), S_{11} (ICR_4), and S_{12} (ICR_5) express the possibility of the company to pay the cost of debt, in a given period t, using financial flow (CF, OCF and UFCF) that directly express the liquidity generated by the firm's cycle; these ratios are qualified as interest coverage ratio with financial approach. The importance of ICRs is considered in several researches (Leland, 1994, 1998) where it is highlighted that interest coverage ratio covenants could reduce asset volatility. Frequently, this type of covenants are applied in bank loan agreements (Gray et al., 2006), as leverage and current ratio; ICRs are frequently used expressing an EBIT or EBITDA to interest expense ratio, having an earnings based approach, as expressed in different studies (Dichev and Skinner, 2002; Demerjian, 2011). In fact, the banks usually include the minimum interest coverage ratio (ICR) that the firm must achieve in the term sheet for financing; the text of the covenants that defines the minimum ICR are frequently expressed in terms of earnings before interest and taxes (EBIT) and/or in terms of earnings before interest, taxes, depreciation, and amortization (EBITDA). In the course of article we compare ICR with economic approach and financial approach to assess if there are statistically significant differences.

RESULTS

The research plan

Data analysis was conducted on a sample of 216 firms operating in fruit and vegetables processing industry in Italy. The data was made available free of charge by analisiaziendale IT company was randomly drawn from the annual accounts in the AIDA database considering 2006 as base year; the data extraction covers the 5-years period from 2006 to 2011 and uses the annual accounts filed by limited companies each year at the Registrar of Companies. In the analysis, a total of 1,080 year-firms have been considered. All the firms considered in the sample are micro (MEs) and small / medium sized

Table 1. Descriptive statistics.

Ratio	N	Mean median		S.Dev.	Kurtosis skewness	
	Stat	Stat	Stat	Stat	Stat	Stat
$S_{1\ EBITDA/TA}$	1,080	0.1933	0.1652	9.273	0.581	0.904
$S_{2\ EBIT/TA}$	1,080	0.1436	0.1147	-2.005	0.565	0.861
$S_{3\ PROFIT/TA}$	1,080	0.2087	0.0946	9.048	3.532	9.794
$S_{4\ CF/TA}$	1,080	0.0860	0.1140	-1.802	-1.742	2.031
$S_{5\ OCF/TA}$	1,080	0.0408	0.0402	.672	0.157	0.855
$S_{6\ UFCF/TA}$	1,080	0.0135	0.0093	-2.860	-0.172	0.182
$S_{7\ FCFE/TA}$	1,080	-0.0868	-0.0520	-2.638	-2.944	17.452
$S_{8\ EBITDA/I^{p}}$	1,080	11.2874	3.6573	-2.297	4.473	74.170
$S_{9\ EBIT/I^{p}}$	1,080	8.6803	2.5077	-0.450	6.068	59.077
$S_{10\ CF/I^{p}}$	1,080	5.4973	2.2018	-2.649	7.722	74.954
$S_{11\ OCF/I^{p}}$	1,080	2.3629	0.8118	3.959	5.767	82.980
$S_{12\ UFCF/I^{p}}$	1,080	.4445	0.1952	1.283	6.353	40.461

(SMEs) enterprises. We define MEs as firms with turnover under 2 million Euro per year, and SMEs are firms with turnover between 2 and 50 million Euro per year. Firms with more of 50 million Euro turnover per year are not considered in the research. MEs and SMEs analysis in the sector could be interesting because these firm's size is characterized by important character: first, MEs and SMEs represent the vast majority of firms number in the sector and, moreover, MEs and SMEs are provided by a large part of the public policies aid in Italy. Data analysis was performed using the statistical package SPSS, issue 19.

Descriptive statistics

The research first considers the analysis of parametric data considered relevant in the sample of firms. We consider EBITDA, EBIT and PROFIT (income margins), and CF, OCF, UFCF, FCFE (financial margins). The analysis conducted during the research, as expressed in the introduction, include the calculation of the following ratios:

1. Sustainability ratios with economic approach (ratios from S_1 to S_3) and financial approach (ratios from S_4 to S_8); these ratios are calculated for all firms in the sample.
2. Interest coverage ratios (ICRs) calculated in accordance with the economic approach (ratios S_8 and S_9) and financial approach (ratios S_{10} and S_{11}).

The descriptive statistics (Table 1) show that the margins are characterized by asymmetry, as expressed by kurtosis and skewness values. In particular, S_3 and S_7 are characterized by higher level of skewness, expressing the volatility of net income and net financial results for equity holders.

We verify the normality of the distribution of income and financial margins applying the Kolmogorov-Smirnov D statistic, having evidence of the not normality of distribution for all considered ratios (Table 2).

Correlation analysis

The correlation calculated with parametric approach, using the Pearson statistic (Table 3), shows significant correlations. EBITDA is highly correlated with EBIT and PROFIT, as income margins, and even with OCF, UFCF and FCFE; at the same time, EBIT is highly correlated with PROFIT, OCF, UFCF and FCFE. It is interesting to consider that PROFIT is not correlated with OCF and UFCF, while is highly correlated with FCFE, expressing that a measure of the economic result, as PROFIT, has a relation with a financial measure available for equity holders, as is FCFE. CF has a positive correlations only with OCF and UFCF, while has a negative correlation with PROFIT, expressing that this financial margin is not able to approximate the most part of income and financial margins. OFC has correlations with EBITDA, EBIT, CF, UFCF and FCFE, while it has no correlation with PROFIT; at the same time, UFCF has correlations with EBITDA, EBIT, CF, OCF, while it has no correlation with PROFIT and FCFE. FCFE has correlations with EBITDA, EBIT, PROFIT, while it has no correlation with CF and UFCF. In general, the correlations between CF / UFCF and other margins are weaker and not statistically significant, even expressing cases of negative correlations.

Considering the result of Kolmogorov-Smirnov D statistic, it could be useful to apply also a non parametric approach of correlation (Spearman ρ). The data (Table 4) confirm the results of the parametric correlation between margins: We can note an increasing in some statistical

Table 2. Kolmogorov-Smirnov D statistic on normality of distribution.

Ratio	Null hypothesis (H_0)	Sign.	Decision
$S_{1\ EBITDA/TA}$	Distribution is normal with mean 0.1933 and S.D. 0.1652	0.000**	Reject null hypothesis
$S_{2\ EBIT/TA}$	Distribution is normal with mean 0.1436 and S.D. 0.1147	0.000**	Reject null hypothesis
$S_{3\ PROFIT/TA}$	Distribution is normal with mean 0.2087 and S.D. 0.0946	0.000**	Reject null hypothesis
$S_{4\ CF/TA}$	Distribution is normal with mean 0.0860 and S.D. 0.1140	0.001**	Reject null hypothesis
$S_{5\ OCF/TA}$	Distribution is normal with mean 0.0408 and S.D. 0.0402	0.002*	Reject null hypothesis
$S_{6\ UFCF/TA}$	Distribution is normal with mean 0.0135 and S.D. 0.0093	0.000**	Reject null hypothesis
$S_{7\ FCFE/TA}$	Distribution is normal with mean -0.0868 and S.D. -0.0520	0.003*	Reject null hypothesis
$S_{8\ EBITDA/I^p}$	Distribution is normal with mean 11.2874 and S.D. 3.6573	0.000**	Reject null hypothesis
$S_{9\ EBIT/I^p}$	Distribution is normal with mean 8.6803 and S.D. 2.5077	0.000**	Reject null hypothesis
$S_{10\ CF/I^p}$	Distribution is normal with mean 5.4973 and S.D. 2.2018	0.000**	Reject null hypothesis
$S_{11\ OCF/I^p}$	Distribution is normal with mean 2.3629 and S.D. 0.8118	0.000**	Reject null hypothesis
$S_{12\ UFCF/I^p}$	Distribution is normal with mean 0.4445 and S.D. 0.1952	0.000**	Reject null hypothesis

**Test is significant at the 0.01 level (2-tailed); *Test is significant at the 0.05 level (2-tailed).

Table 3. Correlation between income and financial margins - parametric approach (Corr. Pearson).

		$S_{1\ EBITDA/TA}$	$S_{2\ EBIT/TA}$	$S_{3\ PROFIT/TA}$	$S_{4\ CF/TA}$	$S_{5\ OCF/TA}$	$S_{6\ UFCF/TA}$	$S_{7\ FCFE/TA}$
$S_{1\ EBITDA/TA}$	Corr. Pearson	1	0.986**	0.075*	0.046	0.506**	0.172**	0.104**
	Sig. (2-tailed)		0.000	0.014	0.135	0.000	0.000	0.001
	N. 1,080							
$S_{2\ EBIT/TA}$	Corr. Pearson	0.986**	1	0.075*	0.040	0.497**	0.169**	0.107**
	Sig. (2- tailed)	0.000		0.014	0.192	0.000	0.000	0.000
	N. 1,080							
$S_{3\ PROFIT/TA}$	Corr. Pearson	0.075*	0.075*	1	-0.086**	0.036	-0.027	0.075*
	Sig. (2- tailed)	0.014	0.014		0.005	0.231	0.374	0.014
	N. 1,080							
$S_{4\ CF/TA}$	Corr. Pearson	0.046	0.040	-0.086**	1	0.101**	0.338**	00.005
	Sig. (2- tailed)	0.135	0.192	0.005		0.001	0.000	0.879
	N. 1,080							
$S_{5\ OCF/TA}$	Corr. Pearson	0.506**	0.497**	0.036	0.101**	1	0.089*	0.218**
	Sig. (2- tailed)	0.000	0.000	0.231	0.001		0.000	0.000
	N. 1,080							
$S_{6\ UFCF/TA}$	Corr. Pearson	0.172**	0.169**	-0.027	0.338**	0.089*	1	-0.017
	Sig. (2- tailed)	0.000	0.000	0.374	0.000	0.000		0.583
	N. 1,080							
$S_{7\ FCFE/TA}$	Corr. Pearson	0.104**	0.107**	0.075*	00.005	0.218**	-0.017	1
	Sig. (2- tailed)	0.001	0.000	0.014	0.879	0.000	0.583	
	N. 1,080							

**The correlation is significant at the 0.01 level (2-tailed); *the correlation is significant at the 0.05 level (2-tailed).

significance of the correlations. Income margins (EBITDA and EBIT) have non parametric correlations with PROFIT and cash flow margin while relations are weaker in the cases of CF and UFCF with others margin. Analyzing the data in absolute values, intermediate income margins (EBITDA / TA and EBIT / TA) and PROFIT / TA have more positive values (in 963, 861 and 748 observations respectively) compare to financial margins, respectively

Table 4. Correlation between income and financial margins - non parametric approach (Spearman's ρ).

		S_1 EBITDA/TA	S_2 EBIT/TA	S_3 PROFIT/TA	S_4 CF/TA	S_5 OCF/TA	S_6 UFCF/TA	S_7 FCFE/TA
S_1 EBITDA/TA	Spearman ρ	1	0.979**	0.311*	0.348**	0.551**	0.295**	0.188**
	Sig. (2-tailed)		0.000	0.014	0.000	0.000	0.000	0.000
	N. 1,080							
S_2 EBIT/TA	Corr. Pearson	0.979**	1	0.306**	0.336**	0.538**	0.282**	0.391**
	Sig. (2- tailed)	0.000		0.000	0.000	0.000	0.000	0.000
	N. 1,080							
S_3 PROFIT/TA	Corr. Pearson	0.311*	0.306**	1	0.115	0.305	0.121	0.202*
	Sig. (2- tailed)	0.014	0.000		0.322	0.231	0.374	0.013
	N. 1,080							
S_4 CF/TA	Corr. Pearson	0.348**	0.336**	0.115	1	0.376**	0.308**	-0.016
	Sig. (2- tailed)	0.000	0.000	0.322		0.000	0.000	0.603
	N. 1,080							
S_5 OCF/TA	Corr. Pearson	0.551**	0.538**	0.305	0.376**	1	0.322**	0.181**
	Sig. (2- tailed)	0.000	0.000	0.231	0.000		0.000	0.000
	N. 1,080							
S_6 UFCF/TA	Corr. Pearson	0.295**	0.282**	0.121	0.308**	0.322**	1	-0.068
	Sig. (2- tailed)	0.000	0.000	0.374	0.000	0.000		0.260
	N. 1,080							
S_7 FCFE/TA	Corr. Pearson	0.188**	0.391**	0.202*	-0.016	0.181**	-0.068	1
	Sig. (2- tailed)	0.000	0.000	0.013	0.603	0.000	0.260	
	N. 1,080							

**The correlation is significant at the 0.01 level (2-tailed); *the correlation is significant at the 0.05 level (2-tailed).

with 827 (CF / TA), 720 (OCF / TA), 581 (UFCF / TA) and 320 (FCFE / TA) positive observations.

Comparison of mean and median of values

In addition to the analysis of correlation between values, it is necessary to determine whether the values of the parameters are statistically significant different. This analysis determines whether the computational approaches (economic and financial) are significantly different, applying comparisons of values. The analysis is firstly conducted with parametric approach, using the Student's t statistic (t-Student) for paired samples to compare the results of different margins. The analysis tests the following 12 null hypotheses: H_1: the S_1 and S_4 ratios have equal means (medians) in the firm's sample; H_2: the S_1 and S_5 ratios have equal means (medians) in the firm's sample; H_3: the S_1 and S_6 ratios have equal means (medians) in the firm's sample; H_4: the S_1 and S_7 ratios have equal means (medians) in the firm's sample; H_5: the S_2 and S_4 ratios have equal means (medians) in the firm's sample; H_6: the S_2 and S_5 ratios have equal means (medians) in the firm's sample; H_7: the S_2 and S_6 ratios have equal means (medians) in the firm's sample; H_8: the S_2 and S_7 ratios have equal means (medians) in the firm's sample; H_9: the S_3 and S_4 ratios have equal means (medians) in the firm's sample; H_{10}: the S_3 and S_5 ratios have equal means (medians) in the firm's sample; H_{11}: the S_3 and S_6 ratios have equal means (medians) in the firm's sample; H_{12}: the S_3 and S_7 ratios have equal means (medians) in the firm's sample. The comparison with parametric approach highlights that in all comparisons is possible to reject the null hypothesis of equality between means (Table 5).

It was also applied a non parametric approach, given the results of Kolmogorov-Smirnov D test (as exposed in Table 2), applying the statistic of Wilcoxon for paired samples (Wilcoxon Matched-Paired Signed Ranks Test). The comparison with non parametric approach highlights, with the exception of the comparisons in the Couple S_2 - S_4 for the ratios EBIT / TA and OCF / TA (significance .607), that in all comparisons is possible to reject the null hypothesis of equality between medians. Two-sided test has significance 1.00% in 11 comparisons: the analysis shows a significant difference between economic margins (EBITDA and EBIT) and financial margins (CF, OCF and UFCF) and confirms parametric analysis results (Table 6).

Table 5. Comparison of economic / financial margins - parametric approach for paired samples (t-Student).

Couples of value		Values and statistics					
		Mean	Standard Dev.	Mean standard error	t	df	Sig. (2-tailed)
Couple 1							0.000**
Couple 2	$S_1 - S_5$	0.15249	0.16038	0.00488	31.248	1,079	0.000**
Couple 3	$S_1 - S_6$	0.17987	0.20737	0.00631	28.505	1,079	0.000**
Couple 4	$S_1 - S_7$	0.28014	0.27275	0.00829	33.754	1,079	0.000**
Couple 5	$S_2 - S_4$	0.05763	0.25913	0.00788	7.310	1,079	0.000**
Couple 6	$S_2 - S_5$	0.10277	0.16233	0.00493	20.807	1,079	0.000**
Couple 7	$S_2 - S_6$	0.13015	0.20848	0.00634	20.516	1,079	0.000**
Couple 8	$S_2 - S_7$	0.23042	0.27288	0.00830	27.750	1,079	0.000**
Couple 9	$S_3 - S_4$	0.11423	0.74608	0.02270	5.032	1,079	0.000**
Couple 10	$S_3 - S_5$	0.15937	0.71167	0.02165	7.359	1,079	0.000**
Couple 11	$S_3 - S_6$	0.18674	0.72155	0.02195	8.505	1,079	0.000**
Couple 12	$S_3 - S_7$	0.28702	0.77672	0.02363	12.144	1,079	0.000**

**Value significant at the 0.01 level (2-tailed); *value significant at the 0.05 level (2-tailed).

Table 6. Comparison of economic / financial margins - non parametric approach for paired samples (T-Wilcoxon).

Couples of value		T-Wilcoxon for paired sample stat.	T-Wilcoxon for paired sample stand. stat.	Observ.	Sig. (2-tailed)
Couple 1	$S_1 - S_4$	4.220	8.160	1,080	0.000**
Couple 2	$S_1 - S_5$	1.032	-11.630	1,080	0.000**
Couple 3	$S_1 - S_6$	1.549	-11.062	1,080	0.000**
Couple 4	$S_1 - S_7$	971.000	11.688	1,080	0.000**
Couple 5	$S_2 - S_4$	11.245	-.515	1,080	0.607
Couple 6	$S_2 - S_5$	7.196	4.918	1,080	0.000**
Couple 7	$S_2 - S_6$	7.072	4.802	1,080	0.000**
Couple 8	$S_2 - S_7$	5.165	-6.919	1,080	0.000**
Couple 9	$S_3 - S_4$	4.342	3.443	1,080	0.000**
Couple 10	$S_3 - S_5$	6.521	5.872	1,080	0.000**
Couple 11	$S_3 - S_6$	7.454	6.294	1,080	0.000**
Couple 12	$S_3 - S_7$	8.441	6.988	1,080	0.000**

**Value significant at the 0.01 level (2-tailed); *value significant at the 0.05 level (2-tailed).

The analysis about sustainability of the cost of debt is performed calculating ICRs; this evaluation has importance for firms to prevent financial crisis as in case of firm's inability to pay the cost of debt and, at the same time, these ratios could be useful for banks to assess the creditworthiness of companies in the sector. In this analysis it is also useful to consider the current state of reduced bank lending (credit crunch) having that assessment of ICRs could offer a significant applied interest. In Italy, in the agro-food sector, credit crunch has hit in particular MEs and SMEs, that are firms involved in the sample here considered. The ICRs calculated using income approach, taking EBITDA and EBIT as numerator, then expressing ICR_1 and ICR_2, have average values 3.1225 and 2.7751, respectively; the ICRs calculated with financial approach, with CF, OCF and UFCF as numerator (ICR_3, ICR_4 and ICR_5) have average values 2.2901, 1.6974 and 0.9182 respectively. The comparison of significance of differences between ICRs calculated with economic and financial approach was firstly calculated (Table 7) applying a parametric approach (Student's t statistic for paired samples). The analysis is articulated considering 6 comparisons, and shows that all comparisons highlight, with the exception of the comparison ICR_2 and ICR_3 (Couple S_9 - S_{10}), that it is possible to reject the null hypothesis of equality between the means applying a two-sided test, with significance 1.00%.

Given the results of Kolmogorov-Smirnov test, we also apply a non parametric approach (Table 8), considering

Table 7. Comparison of economic / financial ICRs - parametric approach for paired samples (t-Student).

Couples of value		Values and statistics					
		Mean	Standard Dev.	Mean standard error	t	df	Sig. (2-tailed)
Couple 1	$S_8 - S_{10}$	5,7901	45,1548	1,3740	4.214	1,079	0.000**
Couple 2	$S_8 - S_{11}$	8,9245	56,1130	1,7074	5.227	1,079	0.000**
Couple 3	$S_8 - S_{12}$	10,8429	79,3804	2,4154	4.489	1,079	0.000**
Couple 4	$S_9 - S_{10}$	3,1830	45,0203	1,3699	2.324	1,079	0.020*
Couple 5	$S_9 - S_{11}$	6,3174	49,6436	1,5106	4.182	1,079	0.000**
Couple 6	$S_9 - S_{12}$	8,2358	73,8156	2,2461	3.667	1,079	0.000**

**Value significant at the 0.01 level (2-tailed); *value significant at the 0.05 level (2-tailed).

Table 8. Comparison of economic / financial ICRs - non parametric approach for paired samples (T-Wilcoxon).

Couples of value		T-Wilcoxon for paired sample stat.	T-Wilcoxon for paired sample stand. stat.	Observ.	Sig. (2-tailed)
Couple 1	$S_8 - S_{10}$	6.336	5.853	1,080	.000**
Couple 2	$S_8 - S_{11}$	3.753	-8.604	1,080	.000**
Couple 3	$S_8 - S_{12}$	2.829	9.666	1,080	.000**
Couple 4	$S_9 - S_{10}$	8.389	-3.433	1,080	.001**
Couple 5	$S_9 - S_{11}$	4.535	-7.618	1,080	.000**
Couple 6	$S_9 - S_{12}$	3.833	8.485	1,080	.000**

**Value significant at the 0.01 level (2-tailed); *value significant at the 0.05 level (2-tailed).

the statistic of Wilcoxon (Wilcoxon Matched-Paired Signed Ranks Test for paired samples). The comparison in pairs with non parametric approach highlights, without exception, that in all comparisons is possible to reject the null hypothesis of equality between the means for two-sided test, with significance 1.00%.

The analysis of the ICRs shows that sustainability assessment has different results applying economic and financial ratios suggested in the article, and financial ICRs are able to express more correctly the firm's capacity to pay the cost of debt in the sector.

The regression analysis

The regression analysis aims to quantify the causal relationship between a variable to be explained (the dependent variable) and one or more explanatory variables (independent variables). Objective of the analysis is to identify the independent variables explaining the variation of the dependent variable, and their impact on dependent variable. In the article we would explain the relation between financial and economic flow; particularly, we are interested in analyze if there was a relation between a financial measure as FCFE, that express the amount of cash available for equity holders, and some independent variables. We have developed an additive linear regression model, as follows, with two regression equations:

$$FCFE_t = \alpha + \beta_1 EBITDA_t + \beta_2 EBIT_t + \beta_3 PROFIT_t + \beta_4 EBITDA_{t-1} + \beta_5 EBIT_{t-1} + \beta_6 PROFIT_{t-1} + \varepsilon \quad (19a)$$

$$FCFE_t = \alpha + \beta_1 CF_t + \beta_2 OCF_t + \beta_3 UFCF_t + \beta_4 CF_{t-1} + \beta_5 OCF_{t-1} + \beta_6 UFCF_{t-1} + \varepsilon \quad (19b)$$

The first model, expressed in (19a), considers $FCFE_t$ as independent variable in a given time (t), which expresses the amount of cash available for equity holders. The constant term is α, EBITDA is explanatory variable considered in values for the years t and t-1 ($EBITDA_t$ and $EBITDA_{t-1}$ respectively), at the same time are considered explanatory variables EBIT and PROFIT, considered in their values at years t and t-1, having then other four explanatory variables ($EBIT_t$ and $EBIT_{t-1}$, $PROFIT_t$ and $PROFIT_{t-1}$). The idea underlying the model is that could be possible to explain actual FCFE (at a given time t) considering, as explanatory variables, the actual income margins (EBITDA, EBIT and PROFIT) and their respective values considered at time t-1 ($EBITDA_t$, $EBIT_t$ and $PROFIT_t$). The model seeks to explain whether the intermediate income margins can be considered adequately explanatory variables of the amount of cash available for equity holders in fruit and vegetables industry. This information is important because the generation of cash flows for equity holders enables small

Table 9. Extract of the multiple regression model that shows the impact on $FCFE_t$ of economic independent variables – model 19a.

Model	Unstandardized coefficient		Standardized coefficient	T	Sig.
	B	Std. error	Beta		
(Constant)	-0.1121	0.023	-		
$EBITDA_t$	0.1299	0.014	0.122	7.011	0.000***
$EBIT_t$	0.0922	0.011	0.136	4.552	0.000***
$PROFIT_t$	0.0877	0.019	0.098	2.859	0.006**
$EBITDA_{t-1}$	0.1192	0.025	0.035	2.531	0.011*
$EBIT_{t-1}$	0.1064	0.033	0.045	2.090	0.040*
$PROFIT_{t-1}$	0.0089	0.051	0.065	1.928	0.061

19a. Dependent variable: $FCFE_t$; ***the relation is significant at the 0.001 level (2-tailed); **the relation is significant at the 0.01 level (2-tailed); *the relation is significant at the 0.05 level (2-tailed).

Table 10. Extract of the multiple regression model that shows the impact on $FCFE_t$ of financial independent variables – model 19b.

Model	Unstandardized coefficient		Standardized coefficient	T	Sig.
	B	Std. error	Beta		
(Constant)	0.2152	0.012	-	60.225	0.000***
CF_t	0.0118	0.080	0.020	0.154	0.875
OCF_t	0.2864	0.005	0.522	30.951	0.001***
$UFCF_t$	-0.0872	0.021	-0.021	-0.859	0.402
CF_{t-1}	0.1025	0.035	0.009	0.965	0.340
OCF_{t-1}	0.4499	0.036	0.461	20.655	0.003**
$UFCF_{t-1}$	0.0122	0.090	0.022	-0.901	0.361

19b. Dependent variable: $FCFE_t$; ***the relation is significant at the 0.001 level (2-tailed); **the relation is significant at the 0.01 level (2-tailed); * the relation is significant at the 0.05 level (2-tailed).

and medium-sized enterprises to attract capital in terms of equity, having impact in increasing the firm's average size. In addition, since these firms are often small and medium-sized, and are based on family labor, the availability of financial resources for distribution to shareholders is essential to ensure the continuity of the business, which is based precisely on the remuneration of shareholders with monetary distribution of dividends and / or their discretionary reinvestment in the firm, even ensuring to improve technical efficiency. The model (19a), analyzed in Table 9, assumes a significant statistical capacity to explain $FCFE_t$ values; F statistic for the considered model has high significance (F = 0.000); R^2 has value 0.833 while adjusted R^2 has the value 0.831 expressing the capacity of the model to explain the great part of the variability of $FCFE_t$; statistic DW is 2.411. In the model 19a, the coefficients of $EBITDA_t$, $EBIT_t$, $PROFIT_t$ are highly significant (0.001 level and 0.01 level); $EBITDA_{t-1}$ and $EBIT_{t-1}$ are relatively significant (significant at the 0.05 level) while $PROFIT_{t-1}$ is not statistically significant (significant at the 0.061 level). It is interesting to note that FCFE is mainly influenced by intermediate income margins of the year while intermediate Income margins of previous years are less important as explanatory variables.

The second model, expressed in (19b), considers $FCFE_t$ as independent variable at a given time (t) considering, as explanatory variables, the actual financial margins (CF, OCF, and UFCF) and their respective values considered at time t-1 (CF_t, OCF_t and $UFCF_t$). This second model would explain whether the intermediate financial margins can be considered adequately explanatory variables of the amount of cash available for equity holders in fruit and vegetables industry, for the same reasons expressed before, about the first model. At the same time we would compare the results of these two models in order to quantify which model is more useful to quantify the variability of the independent variable. The model (19b), analyzed in Table 10, assumes an adequate statistical capacity to explain the performance of $FCFE_t$; F statistic has moderate significance (F = 0.021) while R^2 has quite moderate value that is 0.488 and adjusted R^2 has the value 0.484, expressing the capacity of the model to explain only a part of the variability of $FCFE_t$; statistic DW is 2.004. In the 19b model, the coefficients of OCF_t and OCF_{t-1} are mostly significant (significant at the 0.001 level) while other variables (CF_t, CF_{t-1}, $UFCF_t$ and $UFCF_{t-1}$) are not significant. The model expresses that the variations of FCFE in a given time (t) are only partly influenced by intermediate financial margins and only OCF is quite accurate to express FCFE variations.

DISCUSSION

The cultivation and processing of fruit and vegetables in Italy characterizes the economy of the territories in many parts of Italy. This country is considered one of the major processing country of fruit and vegetables in the basin of the Mediterranean Sea, as some others Mediterranean countries (Spain, Morocco, Tunisia and Turkey). Italy has two main areas of production and processing of fruit and vegetables industry: the first is located in the southern regions, particularly in Sicilia, Puglia and Campania regions, while a second area includes the regions of Emilia-Romagna, Lombardia and Piemonte. The firms in the sector of fruit and vegetables processing are characterized, as is shown in the analysis, by high level of capital investment, in particular to finance investment in plant and machinery. These firms often require investments to achieve a high level of technical efficiency, and to reduce costs of production, and also to ensure food safety standards. Investment in capital equipment, however, needs to be covered with sources of capital that are retrieved with direct contribution of the entrepreneur, as equity capital, or acquiring new capital as debt. This capital requirement could cause financial difficulties, especially for small and medium-sized enterprises, which are disadvantaged in the access to capital market. In fact, small firms have difficulty in acquiring capital by banks because of opacity risk in financing relations due the limited information generally available in applying credit scoring models to SMEs; the need to deep credit analyses could cause excessive cost for banks, especially considering the return on capital loaned to SMEs, and the related risk of firm's default. At the same time, small firms do not have, in general, access to the equity capital market because of their too small size. For firms in the sector of fruit and vegetables processing industry, as considered in the article, the time lag that exists between economic cycle and financial cycle can direct to wrong strategic decisions, with the risk of default for many firms in the sector. In fact, in recent years, the processing companies of the sector have been characterized by a large number of corporate crises, which have also caused bankruptcy and liquidation. Many extraordinary restructuring plans were also performed to avoid firm's bankruptcy. In fact, in the processing of fruit and vegetables sector, many firms have suffered for an increasing in raw material costs and for the recently increased level of competition in the market of the processed product. About this topic, it is to consider that the distribution of finished products is carried out by large retail chains; these firms use their bargaining power to impose trading prices of finished product that are unfavorable for producers, even increasing the average time of suppliers payment, as for processing firms. Many firms, often, have a low level of production differentiation and modest brand loyalty at consumer level; these strategic weaknesses is disadvantageous for bargaining power of processing firms against large retailers, having negative effects in terms of market price and delay in credit payment. All these facts could cause an increasing of the working capital absorption. It is even necessary to consider that some of the firms process only a few number of productions (for example tomato), with a concentration of production in the summer period, with use of seasonal workers in the peak of production, having maintenance, storage and marketing activities in the rest of the year. In other cases, firms conduct a multi-production strategy that includes various vegetable preserves, even considering fruit processing for juice production, also in order to reduce the seasonal nature of the agro-food activity. Given this general context, the analysis conducted in the article, expressing a comparison between Income margins and financial margins, has the aim to identify whether there are statistically significant differences between economic and financial margins in the firms of the sample, given their characterization of high liquidity absorption in the financial cycle of fixed asset and working capital. This case is particularly relevant for the sector, where the majority of firms are classified as small and medium-sized enterprises, as firms where an increase in the value of net working capital (NWC) could generated difficulties in applying to additional source of cash, because of their reduced firm's capacity to obtain bank loans. For the assessment of the sustainability of the business cycle, are frequently applied margins that consider income values as EBITDA and EBIT to approximate cash flow measure. Moreover, it is necessary to express that these margins do not consider: (1) the effect of the revenues to be collected from customers, (2) the purchases not paid to suppliers, (3) the change in value of inventories. Only in a steady state situation (no change in the extension granted and received by customers and suppliers, no variation in the average number of days of inventory, no change in turnover etc.) we have the equality, even with lag time, between income and financial margins (Bonazzi et al., 2012). About this topic, the analysis shows that margins calculated with economic approach, that are EBITDA, EBIT and PROFIT, often differ significantly from the margins calculated with financial approach (CF, OCF, UFCF and FCFE). This shows that income margins do not adequately approximate the creation of financial liquidity generated by the management of the companies in the sector. This is especially true for UFCF and FCFE.

In particular, the values of FCFE are very low due to the high level of debt that companies in the sector reach for financial investments in fixed assets. In addition, sector's firms have often a high level of PROFIT, but this values cannot be distributed to equity holders due to lack of financial liquidity; in fact, firms in the sample have often positive PROFIT (748 cases), while only a limited number of cases of positive FCFE (320), which means that in 428 cases firms are not able to distribute PROFITs to shareholders due to lack of cash available. The ICRs suggested and applied in work showed, again, significant differences compare to traditionally applied ICRs, that have an income approach; the suggested ratios could then be usefully applied by managers and financial institutions, as banks, for the assessment of affordability and sustainability of the business cycle. In fact, the research shows that, in the firm's sample, ICRs with financial approach are lower than ICRs with economic approach and then it is necessary to consider this fact in case of companies ability evaluation to repay debts. In fact, the sustainability assessments carried out with economic approach have an overestimation of the ability of companies to serve debt, thus providing distorted information to the manager of the company. The analysis shows the usefulness of considering cash flow statement's data to evaluate the sustainability cycle, especially if this is related to financing operations; with the cash flow statement approach, it could be possible to take management decision considering data that correctly express financial sustainability of the business cycle. The article shows that EBITDA and others PROFIT margin, traditionally applied to approximate the cash generated from operations, are not adequate for this purpose. In particular, the analysis shows absorption of capital by NWC having that EBITDA is significantly higher than OCF and, likewise, we have a significant absorption of liquidity in investment in fixed asset (FA). The analysis confirms that companies in the fruit and vegetables processing sector are characterized by difficulties in debt service payment: the median value of UFCF / TA (+ 0.0093) is lower than I / TA (+ 0.0426), expressing the inability of firms to cover debt service. At the same time, the analysis in the sample shows a shift between income cycle and financial cycle: median value of PROFIT / TA is + 0.0946 while median value of FCFE / TA is - 0.0520. The analysis of PROFIT then generates distorted information for equity holders, because firms in the sample, although characterized by accounting remuneration, are unable to generate cash flows available to distribute dividends. The analysis of the proposed regression models shows a better interpretations capacity applying the first model (19a) to explain FCFE results; the model expresses that could be possible to quantify actual FCFE, for a given time (t), having as explanatory variables actual income margins ($EBITDA_t$, $EBIT_t$ and $PROFIT_t$) and their respective values considered at time t-1 ($EBITDA_t$, $EBIT_t$ and $PROFIT_t$). The model is able to confirm that intermediate income margins are explanatory variables of the cash amount available for equity holders, in fruit and vegetables industry. In the first model, the coefficients of $EBITDA_t$, $EBIT_t$, $PROFIT_t$ are mostly significant and $EBITDA_{t-1}$, $EBIT_{t-1}$ are relatively significant while $PROFIT_{t-1}$ is not statistically significant. The second model (19b) considers $FCFE_t$ as independent variable at a given time (t) proposing, as explanatory variables, the actual financial margins (CF, OCF, and UFCF) and their respective values, considered at time t-1 (CF_t, OCF_t and $UFCF_t$). The second model has a worst statistical capacity to explain the performance of $FCFE_t$ even if the coefficients OCF_t and OCF_{t-1} are mostly significant (significant at the 0.001 level) while other variables (CF_t, CF_{t-1}, $UFCF_t$ and $UFCF_{t-1}$) are not significant, considering a 0.05 level. It is then possible to express that variations of FCFE in a given time (t) are partly influenced by intermediate financial margins in which only OCF is useful to express FCFE variations. This result allows defining a guideline for managers having the aim to estimate cash flows for shareholders (FCFE) in the sector of fruit and vegetables processing industry.

Conclusion

The analysis in the article, applied to a sample of firms operating in the fruit and vegetables processing industry in Italy, shows that firms in the sample are characterized by high capital absorption in working capital and fixed assets cycle. In the article are calculated intermediate income margins (EBITDA, EBIT and PROFIT, in relations with TA) of the firm's sample; these margins are compare to financial margins (CF, OCF, UFCF, FCFE, in relations with TA). The article shows that there are significant differences between economic and financial margins, and these differences have effect on firm's cycle sustainability. The analysis shows even significant correlation between economic and financial margins; moreover, there are differences in the margins value, thus expressing that the application of economic margins to management decisions could give distorted information. This situation is also present in the calculation of the ICRs. The results are particularly relevant in the sample of firms in the processing of fruit and vegetables that has been analyzed: in fact the firms in the sample require large amounts of capital, in terms of equity capital and / or debt, to finance investment in fixed asset (buildings, plant and equipment for processing) and working capital (inventories, including finished goods, and accounts receivable). In view of the high absorption of capital due to investment and working capital cycle, and due to the high level of debt, it is necessary to assess the sustainability of the business cycle, particularly considering debt payment capacity. The article shows that the suggested ICRs, calculated with financial approach, are statistically different compared to traditional ICRs used in banking covenants and, often, for the calculation of the firm's rating, that are calculated applying income approach. These ratios can be applied also by policy makers, in public intervention actions, to support firms, including credit union actions, to assess financial strength of companies that could receive public aid, thus limiting the risk of inefficient use of public funds. The data analysis of regression models have shown that not only the economic margins, at time t, but also economic margins, at time t-1, are illustrative of the cash flows available for equity holders (FCFE) at time t. This information is also useful for banks, as the financial flow FCFE assumes that is already paid debt service, therefore providing correct information to firm's manager. The research can moreover constitute a base for other empirical research, and in this way it could be possible to test the validity of our conclusions, applying the applied methodology to different sector of the agro-food system, especially in industry characterized by financial constraints, long period of working capital cycle, and high level of capital absorption.

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Grain yield adaptability and stability of blackeyed cowpea genotypes under rainfed agriculture in Brazil

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The present study aimed to evaluate the grain yield adaptability and stability of 20 blackeyed cowpea genotypes under rainfed agriculture in North, Northeastern and Central/Western Brazil. Three parametric methodologies and one non-parametric methodology were used. We found significant differences among genotypes, environments, and interaction between genotypes and environments. The traditional method indicated that the MNC05-832B-230-2-3 line was the most stable but had low grain yield. The linear regression indicated that the California Blackeye-3 and California Blackeye-5 cultivars had wide adaptability and stability. The bi-segmented regression model indicated that the MNC04-783B-7-3 and California Blackeye-3 genotypes exhibited adaptation to favorable and unfavorable environmental conditions, respectively. The non-parametric method characterized the MNC04-783B-7-3 line as the most suitable and stable genotype. Spearman´s rank correlation showed that some methodologies should not be used simultaneously and that others should be used complementary to each other.

Key words: *Vigna unguiculata*, genotype × environment interaction, non-parametric method, parametric method, seed yield.

INTRODUCTION

Cowpea [*Vigna unguiculata* (L.) Walp.] is a legume grown and consumed worldwide, but predominately in tropical regions where rainfed agriculture predominates. In Brazil, several grain types of this crop, which exhibit variations in size, shape, color, and tegument texture, are produced and consumed according to different market demands. Among these grain types, the blackeyed pea subclass (*fradinho* in Portuguese) stands out, and this subclass is characterized by a white, wrinkled tegument with a large black halo (Freire et al., 2012). This subclass is grown mainly in the states of Sergipe, Bahia and Rio de Janeiro and is currently in a process of expansion in the states of São Paulo and Minas Gerais (Freire et al., 2005). The Brazilian blackeyed pea (*fradinho*) is identical to the common blackeyed pea, which is the most grown and marketed blackeyed pea in the United States both as dry and canned beans (Fery, 1990). In Brazil, the blackeyed grain type has great commercial prospects. However, few blackeyed pea cultivars exist with this type of grain. Therefore, to fulfill this shortage and to release cultivars

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Table 1. List of locations from North, Northeastern, and Central/Western Brazil where the assays to evaluate the grain yield (kg ha^{-1}) of the blackeyed cowpea genotypes were performed and their respective geographical coordinates, altitude, soil type and biome.

Location	Federation State	Federation Region	Altitude (m)	Latitude	Longitude	Soil	Biome
Augusto Corrêa	Pará	North	20	1°01'S	46°38'O	Yellow Latosol (Oxisol)	Amazon
Tracuateua	Pará	North	20	1°04'S	46°53'O	Yellow Latosol (Oxisol)	Amazon
Balsas	Maranhão	Northeast	283	7°31'S	46°02'O	Yellow Latosol (Oxisol)	Cerrado (Brazilian savannah)
Gurupi	Tocantins	North	287	11°43'S	49°04'O	Red-Yellow Latosol (Oxisol)	Cerrado (Brazilian savannah)
Primavera do Leste	Mato Grosso	Central-Western	636	15°33'S	54°17'O	Yellow Latosol (Oxisol)	Cerrado (Brazilian savannah)

for the productive sector, an evaluation of genotypes with this type of grain must be performed, including the evaluation of yield, yield adaptability and yield stability in different environments.

Many methodologies using one or more parameters have been proposed to explain the behavior of genotypes tested across a range of environments as follows: methodologies based on the variance of the Genotype × Environment (G × E) interaction (Yates and Cochran, 1938); simple linear regression (Eberhart and Russell, 1966); bi-segmented regression (Silva and Barreto, 1986); modified bi-segmented regression (Cruz et al., 1989); and non-parametric methodologies (Lin and Binns, 1988); Lin and Binns modified by Carneiro (1998). In Brazil, different adaptability and stability methodologies have been adopted in cowpea (Freire et al., 2001, 2002, 2003; Rocha et al., 2007; Barros et al., 2013). The most suitable method for the evaluation and interpretation of results depends mainly on the number of environments assessed, accuracy of data, type of data desired, simplicity of the analysis and simplicity of the interpretation of the results (Cruz et al., 2004). Another aspect that should be considered is the relationship among the methodologies assessed, as it is possible to identify the methodology that best meets the demands of a given improvement program. Studies on other legumes have been conducted aiming to compare methodologies that evaluate the yield adaptability and stability, for example, the assessment of the common bean (*Phaseolus vulgaris* L.) by Pereira et al. (2009). However, there are few studies comparing yield stability and adaptability methodologies in cowpea (Aremu et al., 2007; Almeida et al., 2012). Therefore, the aim of the present study was to assess grain yield adaptability and stability of a group of blackeyed cowpea genotypes cultivated under rainfed agriculture in Brazil.

In addition, this study aimed to perform a comparative study among several methodologies to identify the most suitable methodology for the study of adaptability and stability of cowpea as well as to subsidize the release and/or recommendation of blackeyed cowpea cultivars for agribusiness in Northern, Northeastern and Central/Western Brazil.

MATERIALS AND METHODS

Twenty cowpea genotypes comprising lines of the *Embrapa Meio-Norte* Improvement Program, genotypes introduced from other countries and a commercial cultivar (Poços de Caldas-MG) were assessed. The study was conducted in Northern, Northeastern, and Central/Western Brazil under rainfed conditions in the 2007/2008 crop years. The experiments were carried out in the following locations: Tracuateua and Augusto Corrêa in the state of Pará (PA) in 2007 and 2008; Balsas in the state of Maranhão (MA) in 2008; Gurupi in the state of Tocantins (TO) in 2008; and Primavera do Leste in the state of Mato Grosso (MT) in 2008 (Table 1). Plantings were performed during the same period of commercial cowpea cultivation in each area. Randomized complete block experiments were performed with 20 treatments and four replications. The experimental plots (1.6 × 5.0 m) were similar in all experiments with a 0.5-m spacing between rows and a 0.125-m spacing between pits within rows. The useful plot area comprised the two central rows where data collection for dry grain yield was performed. For statistical analysis, it was assumed that the combination of year and location represented an environment. Thus, although the assays were conducted in five locations, there were seven experimental environments because in two locations, the assays were conducted for two years. Data were subjected to individual analysis of variance for each environment, and a subsequent joint analysis of the environments was performed after assessing the homogeneity of residual variances, through the Bartlett's test. The Scott-Knott test at 5% probability was used for comparison of means. The evaluation of genotype adaptability and stability was performed using the following methods: traditional method (Yates and Cochran, 1938); the method of Eberhart and Russell (1966); the method of Cruz et al. (1989); and the method of Lin and Binns as modified by Carneiro (1998). A comparative study of the methodologies used was conducted to evaluate the existence of a relationship among them. The parameters estimated by the four methods were used to estimate Spearman´s rank correlation coefficient, which was applied to the rank-order of genotypes obtained in each method. The adaptability and stability order was defined based on its own concepts

Table 2. Summary of the individual analysis of variance of grain yield (kg ha^{-1}) for blackeyed cowpea genotypes in the seven environments (location and year) assessed under rainfed conditions in North, Northeastern and Central/Western Brazil.

Location Year	Mean square			CV$^{1/}$ (%)
	Blocks	Genotypes	Error	
	GL = 3	GL = 19	GL = 57	
Tracuateua 2007	73220.96^{ns}	129520.12**	148681.19	17.54
Augusto Corrêa 2007	141900.52*	252258.42**	40069.56	12.75
Tracuateua 2008	152328.09^{ns}	352092.73**	61642.86	13.41
Augusto Corrêa 2008	90132.07^{ns}	311707.05**	96215.13	21.58
Primavera do Leste 2008	254378.01*	505733.61**	89431.67	14.21
Balsas 2008	9860.79^{ns}	420860.60**	103162.23	27.41
Gurupi 2008	33913.94^{ns}	334676.57**	53822.30	15.48

**, * Significant at 1 and 5% probability levels, respectively, according to the F-test; ^{ns} Non-significant. $^{1/}$ Residual coefficient of variation.

and in the number of parameters of each method. Therefore, the genotypes were ranked from 1 to 20 with 1 representing the genotypes exhibiting higher adaptability and stability and 20 representing the less adapted and stable genotypes. The exception to this ranking method included cases where two or more genotypes exhibited equal parameters. In the present study, we adopted the procedure reported by Pereira et al. (2009). Thus, in the traditional method (Yates and Cochran, 1938), which uses a single parameter of stability, the rank-order was attributed based on the environment mean square within the genotype ($MS_{E/G}$). As for the Eberhart and Russell (1966) method, the rank-order number was obtained from the β_{1i} and δ_{ij} values. The parameters β_{1i} and δ_{ij} describe the response of the genotype "i" in all environments, and deviation of the regression of genotype "i" in environment "j", respectively. For the β_{1i} parameter, the difference between the parameter value and unit was used. This difference and the δ_{ij} parameter were ranked in an increasing order, and then the rank-order numbers of these two parameters were averaged allowing the rank-order number for the correlation study to be obtained.

For the Cruz et al. (1989) methodology, the same ranking procedure adopted by Eberhart and Russell (1966) for the β_{1i} and δ_{ij} parameters was used. The parameter β_{1i} accounts response of the ith genotype at improvement of the unfavorable environments. As for the β_{1i} + β_{2i} parameters, which describe response of the ith genotype at improvement of the favorable environments, the ranking was the reverse of β_{1i}, so the genotype with the greatest value for β_{1i} + β_{2i} was ranked first. From the ranking average of these three parameters, the ranking used in the correlation study was obtained. In the Lin and Binns method modified by Carneiro (1998), the genotypes were ranked based on the estimations of P_{if} and P_{id} representing the parameter stability and adaptability of the genotype "i" in favorable and unfavorable environments, respectively. Subsequently, the ranking average of the P_{if} and P_{id} parameters was obtained for the correlation study. As the mean yield is important for recommendation and/or release of cultivars, Pereira et al. (2009) suggested a ranking where the mean yield is added as a parameter for the correlation analysis. Thus, a second ranking was also obtained in the Eberhart and Russell (1966) and Cruz et al. (1989) methods taking account simultaneously the ranking based on mean yield.

All analyses were performed using SAS (Sas Institute, 2002) and Genes (Cruz, 2006) statistical packages.

RESULTS AND DISCUSSION

In this study, the results indicated significant difference among blocks in only two environments, thereby indicating that the experimental areas were fairly uniform. However, genotypes effect showed significant differences in all environments, thereby indicating a genetic variability for yield among genotypes (Table 2). The Bartlett's test, which evaluate if the residual variances are homogenous, allowed the joint analysis of the assays in the present study. The residual coefficients of variation ranged from 12.75 to 27.41% indicating a satisfactory experimental accuracy. The joint variance analysis showed significant differences (P<0.01) for the effects of environments, genotypes and the genotype × environment interaction. The magnitude of environment effect (89.23%) was higher than the genotype effect (7.83%), which itself was higher than the G × E interaction (2.94%). This result indicated a large difference among environments resulting in differences among environmental means and, consequently, in the genotype yields. Akande (2007), Rocha et al. (2007) and Sarvamangala et al. (2010) found similar results in cowpea studies for the effect of genotypes, environments and the G × E interaction. The joint analysis showed a residual coefficient of variation of 17.05% indicating good experimental accuracy (Table 3). Significant differences among genotypes were found in six assays. The evaluation of the yield behavior of genotypes in different environments showed that the yield ranged from 759.19 (for the Poços de Caldas-MG cultivar in the Balsas location) to 2695.00 kg ha^{-1} (for the MNC04-783B-7-3 line in the Primavera do Leste location) in 2008. In 2007, significant differences were found only among genotypes in the Augusto Corrêa location, especially for

Table 3. Summary of the joint analysis of variance of grain yield (kg ha^{-1}) for the 20 blackeyed cowpea genotypes assessed in seven environments under rainfed agriculture in North, Northeastern and Central/Western Brazil.

Source of variation	df	Mean square	Percentage of variation
Blocks/environments	21	107962.15^{ns}	
Environments (E)	6	8104813.48**	89.23
Genotypes (G)	19	711890.72**	7.83
G × E	114	265826.40**	2.94
Error	399	71133.20	
Mean (kg ha^{-1})		1564.24	
CV (%)		17.05	

df = Degrees of freedom, CV = coefficient of variance, ** significant at P<0.01 according to the F-test; ^{ns} non-significant difference.

the MNC05-820B-173-2-1 line. In 2008, two or more yield groups were found for each environment based on the Scott-Knott test (P<0.05), and the highest yield was found for the MNC04-783B-7-2-1 line in all groups.

In addition to this line, the MNC04-786B-87-2, MNC04-785B-77, and MNC04-789B-119 lines stood out because they were ranked in the first yield group in at least four environments. When considering only the mean of the locations, the yields ranged from 1171.43 kg ha^{-1} in Balsas to 2103.53 kg ha^{-1} in Primavera do Leste in 2008 (Table 4). The grain yields of the lines mentioned earlier in the present study were greater than the mean grain yield of cowpea cultivars released in Northern, Northeastern, and Central/Western Brazil regions with average yields of 1100.50, 1083.00, and 1265.20 kg ha^{-1}, respectively (Freire et al., 2012). The traditional method identified MNC05-832B-230-2-3 and California Blackeye-3 genotypes as the most stable among the groups assessed, but they exhibited low yield (Table 5). These data confirmed the assumption of Cruz et al. (2004), who assumed that genotypes with regular behavior [that is, low $MS_{(G/E)}$] in a range of environments are generally not productive. The adaptability and stability analysis through linear regression (Eberhart and Russell, 1966), excluding parameter of mean yield, indicated that the California Blackeye-5 and California Blackeye-3 cultivars as well as the UCR-2-1 and MNC04-789B-2-3 lines were the best genotypes. Although, they did not have the best grain yields, the aforementioned genotypes exceeded the overall mean of the assays and showed a highly predictable behavior ($\delta_{ij} = 0$) and wide adaptability ($\beta_{1i} = 1$).

Freire et al. (2001, 2002), Santos et al. (2008) and Yousaf and Sarwar (2008) found similar results with cowpea. These authors found that the best-adapted and stable genotypes in most of the cases are not the most productive genotypes but that they achieve an above average yield. Using the method proposed by Cruz et al. (1989), only the MNC05-832B-230-2-3 line, MNC05-832B-230-2-1 line and California Blackeye-3 cultivar of the genotypes assessed showed a β_{1i} estimate lower than 1 (P < 0.05) indicating that these genotypes were adapted to less favorable environments. As for the $\beta_{1i} + \beta_{2i}$ parameter, only the MNC04-783B-7-3 and MNC04-789B-119 lines showed results significantly greater than 1 ($\beta_{1i} + \beta_{2i} \neq 1$), which indicated that they were adapted to more favorable environments and responsive to environmental improvement. As for the δ_{ij} parameter, all genotypes, except for the MNC05-832B-230-2-1 line, showed a deviation of the regression equal to zero ($\delta_{ij} = 0$), which indicated that they were classified as stable in both favorable and unfavorable environments. Based on these results, the best genotype (that is, the one that features a high mean value, $\beta_{1i} < 1$, $\beta_{1i} + \beta_{2i} > 1$ and $\delta_{ij} = 0$) was not found among the genotypes evaluated.

According to the Lin and Binns (1988) method modified by Carneiro (1998), the best genotype was the MNC04-783B-7-3 line because it obtained the lowest estimate of the overall P_i parameter, the second lowest estimate for favorable environments, the lowest estimate for unfavorable environments, and the highest overall mean for yield, which indicated general adaptation and high predictability. In studies with cowpea, Adewale et al. (2010) and Shiringani and Shimelis (2011) found similar results regarding the P_i parameter, thereby confirming that the most adapted and stable genotypes are always related to high yields. According to Cruz and Carneiro (2006) and Pereira et al. (2009), a great advantage of the Lin and Binns (1988) method is the immediate identification of the most stable genotypes due to the uniqueness of the P_i parameter, but this method shows only one parameter estimate for the general recommendation of cultivars. However, the modification of the method proposed by Carneiro (1998) enables an estimation of P_i for favorable and unfavorable environments conferring more robustness to the method.

In the assessment of relative efficiency of methodologies using Spearman's correlation, we found that nine of the 21 correlations estimated were significant. Therefore, it can be inferred that at a greater or lesser efficiency level, the methods used assessed the adaptability and stability of the genotypes and that there was a certain level of

Table 4. Mean grain yield (kg ha^{-1}) of 20 blackeyed cowpea genotypes assessed in seven environments (location and year) under rainfed agriculture in North, Northeastern and Central/Western Brazil.

Genotype	Grain yield (kg ha^{-1})[1]							Overall mean (kg ha^{-1}) (to show the Scott-Knott test)
	2007		2008					
	Tracuateua	Augusto Corrêa	Tracuateua	Augusto Corrêa	Balsas	Gurupi	Primavera do Leste	
MNC04-783B-7-3	1316.69^{a}	1749.46^{b}	2431.13^{a}	1928.83^{a}	1776.31^{a}	1886.53^{a}	2695.00^{a}	1969.13^{a}
MNC04-786B-87-2	1147.69^{a}	1872.99^{b}	2315.81^{a}	1877.10^{a}	1674.69^{a}	1193.70^{c}	2655.00^{a}	1819.56^{b}
MNC04-789B-119	1159.00^{a}	1346.50^{c}	2085.13^{a}	1510.78^{a}	1675.81^{a}	1832.78^{a}	2249.50^{b}	1694.21^{c}
MNC04-785B-77	1504.81^{a}	1832.58^{b}	1738.81^{b}	1391.90^{b}	1302.00^{b}	1428.48^{c}	2630.25^{a}	1689.83^{c}
California Blackeye-5	1529.13^{a}	1585.22^{c}	1783.17^{b}	1678.88^{a}	1217.75^{b}	1873.32^{a}	2043.00^{c}	1672.92^{c}
UCR-A-31	1453.38^{a}	1554.14^{c}	1726.63^{b}	1718.35^{a}	795.03^{b}	1745.11^{a}	2288.50^{b}	1611.59^{c}
UCR-2-1	1262.63^{a}	1388.05^{c}	1881.44^{b}	1553.38^{a}	1080.13^{b}	1857.45^{a}	2236.25^{b}	1608.41^{c}
California Blackeye-3	1508.63^{a}	1402.17^{c}	1830.13^{b}	1455.15^{a}	1455.31^{a}	1485.80^{b}	2105.25^{c}	1604.63^{c}
MNC04-789B-2-3	1473.94^{a}	1588.06^{c}	1684.94^{b}	1272.85^{b}	1191.25^{b}	1708.13^{a}	2228.75^{b}	1592.56^{c}
MNC04-789B-2-1	1126.56^{a}	1663.85^{b}	2121.88^{a}	1105.40^{b}	925.38^{b}	1545.53^{b}	2438.00^{b}	1560.94^{c}
MNC05-820B-173-2-1	1229.75^{a}	2178.86^{a}	1688.69^{b}	1351.40^{b}	1140.88^{b}	1261.43^{c}	1993.25^{c}	1549.18^{d}
MNC05-820B-240	1303.63^{a}	1497.08^{c}	1865.00^{b}	1774.45^{a}	1063.19^{b}	1531.18^{b}	1731.75^{d}	1538.04^{d}
MNC05-832B-230-2-3	1432.63^{a}	1823.23^{b}	1807.69^{b}	1464.89^{a}	1644.00^{a}	1103.10^{c}	1466.00^{d}	1534.50^{d}
TVu-1489	1412.06^{a}	1570.78^{c}	1785.13^{b}	1551.03^{a}	966.94^{b}	1153.80^{c}	1976.75^{c}	1488.07^{d}
MNC05-832B-230-2-1	1614.69^{a}	1071.18^{d}	2383.72^{a}	1043.70^{b}	1245.19^{b}	1486.83^{b}	1376.00^{d}	1460.18^{d}
Vaina Blanca	1077.19^{a}	1632.91^{c}	1812.62^{b}	1493.78^{a}	981.56^{b}	1106.10^{c}	1933.75^{c}	1433.98^{e}
California Blackeye-27	922.56^{a}	1469.42^{c}	1437.81^{c}	1344.38^{b}	902.69^{b}	1571.38^{b}	2183.25^{b}	1404.49^{e}
Poços de Caldas-MG	1398.00^{a}	1441.75^{c}	1832.13^{b}	942.90^{b}	759.19^{b}	1245.60^{c}	2094.75^{c}	1387.76^{e}
MNC05-820B-173-2-2	1345.19^{a}	1553.33^{c}	1539.72^{c}	1273.53^{b}	827.88^{b}	1092.38^{c}	1979.25^{c}	1373.04^{e}
IT82D-60	1165.56^{a}	1164.20^{d}	1264.43^{c}	1016.23^{b}	803.56^{b}	1862.35^{a}	1766.50^{d}	1291.83^{e}
Overall mean (kg ha^{-1})	1319.16	1569.28	1850.80	1436.94	1171.43	1498.54	2103.53	1564.24

[1]Means followed by the same letters in the column belong to the same clustering according to the Scott-Knott test at P<0.05; CV = coefficient of variance.

Table 5. Parameters of adaptability and stability of 20 blackeyed cowpea genotypes assessed in seven environments under rainfed agriculture in North, Northeastern, and Central/Western Brazil according to the traditional method (Yates and Cochran, 1939), Eberhart and Russell method (1966), Cruz et al. (1989) method, and the Lin and Binns method modified by Carneiro (1998).

Genotype	Mean (kg ha^{-1})	Traditional		Eberhart and Russell (1966)				Cruz et al. (1989)					Carneiro (1998)			
		$MS_{(E/Gi)}$	R[1]	β_{1i}	δ_{ij}	R[1]	R_m^2	β_{1i}	$\beta_{1i}+\beta_{2i}$	δ_{ij}	R[1]	R_m^2	P_i	P_{if}	P_{id}	R[1]
MNC04-783B-7-3	1969.13	839927.01**	17	1.26^{ns}	39655.87**	11	5	1.10	1.78	-452007.39^{ns}	1	1	19.51	30.73	11.10	1
MNC04-783B-87-2	1819.56	1209658.01**	19	1.39*	108300.37**	17	12	1.37	1.46	-435868.64^{ns}	5	3	58.54	18.07	88.88	2
MNC04-789B-119	1694.21	614469.45**	10	0.92^{ns}	62498.78**	5	4	0.68	1.70	-245590.13^{ns}	3	2	100.45	168.50	49.42	3

Table 5. Contd.

MNC04-785B-77	1689.83	832584.66**	15	1.27^{ns}	34525.27*	12	8	1.21	1.45	-433026.72^{ns}	4	4	95.61	100.56	91.89	4
California Blackeye-5	1672.92	283237.68**	3	0.70^{ns}	611305^{ns}	14	3	0.66	0.85	-125768.58^{ns}	12	9	112.80	199.56	47.74	5
UCR-A-31	1611.59	797178.51**	14	1.20^{ns}	43676.18**	8	10	1.16	1.36	-300611.75^{ns}	8	6	150.36	175.30	131.65	9
UCR-2-1	1608.41	654189.49**	11	1.14^{ns}	17838.81^{ns}	7	2	1.01	1.59	-384330.95^{ns}	2	5	134.90	189.66	93.84	6
California Blackeye-3	1604.63	275685.05**	2	0.73^{ns}	9842.00^{ns}	13	6	0.54	1.31	-188402.16^{ns}	6	7	130.07	218.70	63.60	7
MNC04-789B-2-3	1592.56	469322.24**	5	0.96^{ns}	872969.00^{ns}	2	1	0.90	1.18	-258952.22^{ns}	10	10	139.10	187.20	103.03	8
MNC04-789B-2-1	1560.94	1263236.70**	20	1.72**	-1121.78^{ns}	19	9	1.81	1.45	-895455.08^{ns}	7	8	155.97	71.15	219.58	10
MNC05-820B-173-2-1	1549.18	669213.00**	12	0.93^{ns}	77804.04**	4	14	1.33	-0.37	-381560.77^{ns}	20	17	165.69	173.94	159.51	11
MNC05-820B-240	1538.04	321647.63**	4	0.67*	22784.76*	15	16	0.74	0.45	-96044.92^{ns}	18	13	176.32	285.52	94.42	12
MNC05-832B-230-2-3	1534.50	250672.86**	1	0.10**	56155.62**	20	17	0.33	-0.65	858994.00^{ns}	17	15	207.51	337.59	109.95	14
TVu-1489	1488.07	484632.08**	6	0.96^{ns}	14481.89^{ns}	3	7	1.02	0.75	-248348.75^{ns}	16	16	191.33	217.16	171.97	13
MNC05-832B-230-2-1	1460.18	837062.17**	16	0.51**	200659.96**	18	19	0.47	0.64	189018.03**	15	14	299.59	494.82	153.16	18
Vaina Blanca	1433.98	583850.49**	8	1.08^{ns}	14868.42^{ns}	6	11	1.24	0.56	-353042.58^{ns}	19	20	212.78	210.01	214.85	15
California Blackeye-27	1404.49	751545.67**	13	1.22^{ns}	26646.39*	9	15	1.19	1.30	-398143.97^{ns}	9	11	245.35	291.97	210.39	16
Poço de Caldas-MG	1387.76	875686.30**	18	1.34*	24091.44*	16	18	1.38	1.22	-501831.91^{ns}	11	12	266.19	210.4	308.04	17
MNC05-820B-173-2-2	1373.04	542949.72**	7	1.03^{ns}	15475.92^{ns}	1	13	1.10	0.78	-291337.72^{ns}	14	18	266.45	283.03	254.03	19
IT82D-60	1291.83	598767.94**	9	0.76^{ns}	89833.50**	10	20	0.66	1.11	-62004.04^{ns}	13	19	373.87	542.13	247.67	20

**, * Significantly different at P<0.01 and P<0.05, respectively, according to the t-test; ^{ns} Non-significant difference; [1] R, genotype rating considering the average positioning between the parameters of methodologies; [2] R_m, rating obtained based on the average positioning between R and the mean yield of the genotype.

association among them (Table 6). The ranking of genotype yields showed the highest correlations with the rankings of the parameters obtained from the Cruz et al. (1989) method, the $Cruz_{mean}$ method, and Lin and Binns method modified by Carneiro (1988). This result showed that the genotypes identified as the most stable and adapted through these methods were also the most productive. Conversely, the Eberhart and Russell (1966) and traditional methods showed no significant correlation with yield indicating that the genotypes considered the most stable and adapted according to these methods were not the most productive. The Lin and Binns method modified by Carneiro (1988) showed median correlation (0.69) with method of Cruz et al. (1989). Conversely, the Lin and Binns method modified by Carneiro (1988) and the Cruz et al. (1989) method showed no significant correlation with the traditional and Eberhart and Russell (1966) methods. The results may be explained by the fact that traditional and Eberhart and Russell (1966) methods assess the adaptability and stability through the minimum variance between environments. Therefore, the Lin and Binns method modified by Carneiro (1988) and the Cruz et al. (1989) methods were the most efficient in the estimation of adaptability and stability of genotypes compared to the traditional and Eberhart and Russell (1966) methods. Pereira et al. (2009) and Almeida et al. (2012) found similar results for the correlation between the Lin and Binns method modified by Carneiro (1988) and the Eberhart and Russell (1966) method.

Conclusion

The MNC04-783B-7-3, MNC04-786B-87-2, MNC04-789B-119, and MNC04-785B-77 lines stood out with high yields, high yield adaptability, and high yield stability, and these lines have the potential to be released for cultivation in Northern, Northeastern and Central/Western Brazil. The Lin and Binns method modified by Carneiro (1988) and the Cruz et al. (1989) method were the most efficient to estimate yield adaptability and stability of the genotypes. The Lin and Binns method modified by Carneiro (1988) and the Cruz et al. (1989) method should not be used concurrently in

Table 6. Estimates of Spearman's rank correlation for each pair of methods and grain yield (kg ha^{-1}) from 20 blackeyed cowpea genotypes assessed in seven environments under rainfed agriculture.

Method	Traditional	E and R(1)	E and R_{mean}(4)	Cruz (2)	$Cruz_{mean}$ (4)	L and B (3)
Yield	-0.18	-0.04	0.47*	0.67**	0.85**	0.98**
Traditional		0.39	0.34	-0.42	-0.35	0.13
E and R			0.80**	0.01	-0.03	-0.06
E and R_{mean}				0.37	0.43	0.55*
Cruz					0.92**	0.69**
$Cruz_{mean}$						0.85**

(1) Eberhart and Russell (1966), (2) Cruz et al. (1989), (3) Lin and Binns modified by Carneiro (1998), (4) Eberhart and Russell (1966) and Cruz et al. (1989) using the mean as one of the parameters. **, * significant at 1 and 5% probability, respectively, according to the t-test.

the evaluation of adaptability and stability of cowpea genotypes.

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Full Length Research Paper

A highly efficient and improved protocol for exploitation of somaclonal variation for enhancing alien gene introgression in wide cross hybrid of *Oryza sativa/Oryza brachyantha*

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The objective of the present study was to develop an effective protocol for optimum callus induction, duration of culture and size of explants of primordial panicle of inter-genomic hybrid of Oryza *sativa/* Oryza *brachyantha*. It was observed that, primordial panicle at very young stage (0.5 to 1.5 cm) takes hardly 5 to 7 days for callus initiation. The two basic media tested, the Murashige and Skoog (MS) medium and Chu's N_6 medium supplemented with 2-4-D, NAA and kinetin (2 mg L^{-1} 2 mg L^{-1} and 1 mg L^{-1}) was better for callus growth and proliferation. In this medium, callus was sub-cultured continuously for 12 passages (12 months) without loss of totipotency. Plantlet regeneration in MS medium was examined using two cytokinins (KIN and BA) along with one auxin NAA at various concentrations and combinations. Tests indicated that, good plant regeneration could be best effected without BA, but with 1.5 to 2.0 mg L^{-1} of KIN at fixed level of NAA (at 0.5 mg L^{-1}).

Key words: Somaclonal, callus, subculture, wide cross, MS medium, N_6 medium.

INTRODUCTION

Improvement in plant breeding techniques in present century have resulted in increased yields and solved many problems associated with disease, insects, harvest, and quality. The plant breeders have, historically, utilized the variability in land races for selection and improvement of crops. However, as modern varieties are planted on much of the cultivated acreage and as human population centres expand, many land races that were developed by our ancestors, are no longer grown and the associated wild species which coexisted with land races in their natural habitat are becoming extinct. In addition, the variability and germplasm resources available for many cultivated varieties are becoming extremely limited (Harlan, 1976). As additional genetic resources are required to enrich the germplasm, unique and imaginative procedures are required to exploit fully the potential of our crop plants. Utilization of wild species, therefore, is one method designed to introduce additional germplasm into cultivated varieties (Stalker, 1980). The reason for leaving the wild species until last decade is well enough known as listed by (Harlan, 1976) who stated that:

(a) Wild species are often more difficult to cross and the hybrids when formed may be completely or partially sterile
(b) There may be difficulties with various ploidy levels
And consequent sterility
(c) A knowledge of the taxonomy, phylogeny a

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geographical distribution of the wild species is often needed before the best use of them can be made and this knowledge is often lacking
(d) Most important of all, wild species possess a whole syndrome of undesirable characters, like shattering, awns, high foliage, low yield, poor flavour and unfavorable agronomic features long with many desirable traits for biotic and abiotic stresses.

This means that, a long and tedius programme of back crossing to the cultigen is necessary with selection for the one feature of interest from the wild species at each backcross generation. Linkages pose serious handicap but it can be broken with difficutly (Harlan, 1976; Stalker, 1980). The wild relatives of cultivated rice are a rich source of genes for resistance to diseases and pests (Heinrichs et al., 1985; Jena and Khush, 1984; Khush et al., 1977, Amante et al., 1990) and many other morphological and physiological traits for high harvest index and photosynthetic efficiency (Swaminathan, 1988). However, efforts to introgress useful genes from wild species to cultivated rice have started only during last decade and therefore very few examples of alien transfer of useful genes have been reported so far.

A gene for grassy stunt virus resistance from one Assam collection of Oryza nivara has been transferred to cultivated rice (Khush et al., 1977).A cytoplasmic factor from O. perennis to develop cytosterile lines for hybrid seed production has also been reported (lin and Yuan,1980).Wide hybridization using Oryz longistaminata and Oryz rufipogon with Oryza sativa (Taillebois, 1983) have been resulted in development of cytoplasmic male sterile lines for use in hybrid rice production. Still inumerable alien traits of interest remain untapped in Oryza. In a recent compilation of useful Oryza germplasm, (Vaughan (1989) rightly stated that, “the chance of finding resistance to insect pests of rice is about 50 times greater in wild Oryza species than the cultigen”. The genus Oryza has about 20 species of which two are cultivated. O. sativa, the Asian cultivated rice is cultivated throughout the world and glaberrima glaberrima is limited to West Africa. They have their close wild relatives, O. nivara, O. rufipogon in Asia and Oryza barthii and O. longistaminata in Africa. In cuba, there is also one species designated as Oryza glumaepatula (formerly O. cubensis) and one Oryza meridionalis in Australia. All these share a common genome which is designated AA. They are all diploid (2n = 24) and are easily crossable and interspecific hybrid within this genome show regular chromosome pairing and recombination, although inter varietal hybrid sterility, gametic sterility genes partial desynaptic genes impose certain problems in low recovery of recombinant phenotypes. Growing large population and selecting desirable parents may circumvent these problems. Thus, gene transfer between these species can be achieved easily and priority should be given for alien gene transfer through wide hybridization as advocated by (Sitch et al., 1989).

Exploitation of somaclonal variation has been demonstrated in a number of plant species including cereals such as wheat, corn and rice (Larkin and Scowcroft, 1981; Larkin et al., 1984). The origin of somaclonal variation, though precisely not known, is postulated to have arisen due to changes in chromosome structure and number, cryptic chromosome rearrangement, changes in transposable elements, somatic reduction and gene amplification and deletion (Larkin and Scowcroft, 1981).

Somaclonal variation has been employed for enhancing bivalent formation in a sterile hybrid of *Hordeum vulgare* × *H.jubetum* Orton (1980) and Lapitan et al. (1984) reported a high degree of chromosome structural changes in amphidiploids of wheat × rye. Recovery of regenerants with 24 pair having alien chromosome insertion from Oryza *latifolia* into *O. sativa* also has been reported. This technique therefore, seems promising in enhancing frequency of genetic exchange between alien and cultivated genome in wide hybridization programme of rice.

With refinement of tissue culture technique and advent of new genetic engineering tools, incorporation of genes from diverse sources have been increasingly used in crop improvement and rice being the world’s premier crop is no exception to it and in the national and international funding agencies has come forward to sponsor many crop improvement programmes in rice. Global rice biotechnology programme of Rockefeller foundation have come out with massive support and promising results have been obtained. In all these wide hybridization is one of the key components in programme aiming at transferring alien genes from diverse sources ser mounting sexual barriers. Now wide hybridization derives support of *in vitro* and *in vivo* fertilization, embryo rescue, anther and ovule cultures, chromosome engineering including amphidiploidy and aneuploidy induction and utilization, somatic hybridization, protoplast fusion and transformation and recombinant DNA technology and somatic cell culture. This along with a well defined conventional breeding programme is going to revolutionise the rice improvement.

Keeping in view of the problems encountered in alien gene transfer through wide hybridization and the emerging scenario of the rice tissue culture and biotechnology programme integrated with breeding and genetics, the present research programme on wide hybridization in rice was undertaken with the following objectives.

MATERIALS AND METHODS

Collection of inflorescence

Healthy tillers containing immature inflorescence (between 0.5 to 2.5 cm size) of F1 wide cross hybrid of *O. sativa/O. brachyantha* were collected.

Table 1. Effect of growth regulators of callus induction frequency of immature inflorescence of *sativa / brachyantha* hybrid.

Growth hormones (mg L^{-1})			Callus induction frequency (%)		Peak callusing duration (days)		Proportion of embryogenic calli (%)	
2,4-D	KIN	NAA	MS	N_6	MS	N_6	MS	N_6
1.0	0.5	-	26	16	20	23	10	6
1.5	0.5	-	44	24	17	19	22	14
2.0	0.5	-	54	48	19	30	30	20
2.5	0.5	-	46	60	17	30	20	11
1.0	1.0	-	20	14	17	15	4	-
1.5	1.0	-	64	44	13	13	36	16
2.0	1.0	-	100	74	7	9	90	56*
2.5	1.0	-	76	64	10	12	34	30
1.0	-	1.0	20	14	18	13	-	-
1.5	-	1.0	24	24	15	11	14	4
2.0	-	1.0	42	42	17	19	-	16
2.5	-	1.0	36	36	13	22	24	8
1.0	-	2.0	22	10	17	25	6	-
1.5	-	2.0	42	26	19	21	6	2
2.0	-	2.0	34	38	17	19	14	4
2.5	-	2.0	30	34	22	22	20	14
1.0	-	2.0	26	22	21	15	-	-
1.5	-	2.0	56	42	13	11	20	18
2.0	-	2.0	100	88	7	8	94	66
2.5	-	2.0	76	58	9	11	42	30

*Concentration of sucrose was kept constant at 3% (W/V).

Surface sterilization and incubation

Immature inflorescence (between 0.5 to 2.5 cm size) of F1 of *O. sativa/O. brachyantha* were collected by cutting below the upper most visible node approximately at the time of swelling for booting. After stripping off their outer leaves, the collected tillers were surface sterilized by two step procedure. First, after removing outer whorls of leaves and sheaths, intact tillers were dipped in 70% (v/v) ethanol for 3 min. Portions of the tillers (10 cm above the node) containing immature inflorescence were excised. Selected segments were sterilized in commercial bleach solution Teepol, 50% (v/v) for 1 h, followed by five thorough washings in sterile distilled water to remove the bleach. Second immature inflorescences of the sizes ranging from 0.5 to 2.5 cm or more were cut, and asceptically excised and individually cultured in culture tubes of 25 × 150 mm size containing suitable medium. The analysis of the data was done using statistical software SAS 9.2. (2010).

Culturing

The cultural conditions were similar to those of embryos excepting the incubation of materials under fully illuminated conditions, with fluorescence tube (Philips, India) having a photoperiod of $132/^{u}$ $Em^{-2}S^{-1}$.

Sub-culturing

After induction of calli in about 7 to 10 days, the calli aseptically transferred onto suitable media for proliferation and this procedure is repeated up to 12 passages in some of the hybrids.

Hardening of seedlings

Since seedlings are grown asceptically under controlled environment to ensure their survival, it is necessary to gradually acclimatize them before transferring them into soil. The culture tubes with seedlings were first transferred to normal room temperature (30 to 35°C and kept for two days. After removing the cotton plugs, the semisolid medium around the seedlings was washed gently under a slow jet of running water. Seedlings were left in glass tray containing tap water for 5 days to encourage initiation of new roots. They were then transferred to liquid growth medium and was allowed to grow for one week.

Transfer of seedlings to soil

Finally, plants were transferred to shallow pan pots containing sterilized, well puddle soil and kept in green house for 3 weeks. Later, plants were transferred to the earthen pot or to the field directly.

RESULTS

Two basal media, MS and N_6 were tested for callusing efficiency of the cultured panicle primordia of *O. sativa x O. brachyantha* hybrid. Two levels of auxins (2, 4-D and NAA) and one cytokinin (KIN) were used in several combinations. The results of the various combinations attempts along with their response are summarised in Table 1.

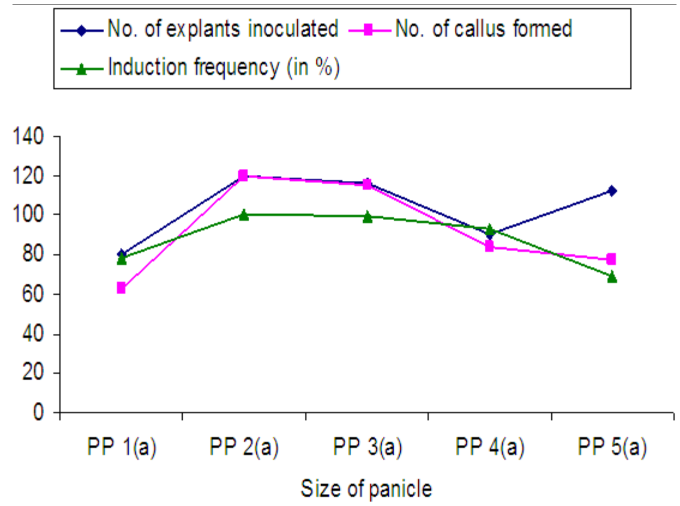

Figure 1. Effect of size of explants on callus induction.

Figure 2. Callus induction from immature inflorescences.

When the level of KIN (0.5 mg L^{-1}) was constant with varying levels of 2, 4-D, the callus induction frequency was high (54%) at 2.0 mg L^{-1} of 2, 4-D with Murashige and Skoog (MS) medium, whereas in N_6 medium the response was highest (60%) when 2.5 mg L^{-1} of 2,4-D was supplemented. In both the media, the callusing frequency was low at lower levels of 2, 4-D (Table 1). However, peak callusing period was delayed and proportion of embryogenic calli obtained was low in N_6 medium when compared to MS medium (Figures 1 and 2). Interestingly, when the level of KIN was increased to 1.0 mg L^{-1} and 2, 4-D being tested under similar concentrations as earlier, it was observed that, 100% callusing was obtained in the MS medium (Figure 2) containing 2.0 mg l^{-1} of 2,4-D, while at the same concentrations, the response in N_6 medium was comparatively low (74%). Conversely both in MS and N_6 media, the peak callusing period were much less (7 and 9 days, respectively). However, proportion of embryogenic calli was as high as 90% under MS medium, while it was only 56% in N_6 medium (in both the medium the callus induction was reduced at higher concentration of 2,4-D). Observation on the effect of 2, 4-D at a fixed level of NAA (1.0 mg l^{-1}) revealed very low frequency of callus induction in both MS and N_6 media at all concentration tested. When the concentration of NAA was inceased to 2.0 mg l^{-1}, there was no substantial increase callus induction frequency over that of 1.0 mg l-1 of NAA and the recovery of embryogenic calli was also less under both the media.

The period of callusing was generally increased in N_6 medium while there was no significant increase or decrease in the case of MS medium. The interaction of 2,4-D with fixed levels of NAA (1.0 mg l^{-1}) and KIN (1.0 mg l-1) revealed that, maximum induction frequencies of 100 and 88% respectively could be obtained quickly (7 to 8 days) when 2.0 mg l^{-1} of 2,4-D was supplemented to MS and N_6 media. However, the proportion of embryogenic calli was high (94%) in MS medium and low (66%) in N_6 medium. To identify suitable size of the explants for maximum callusing in *O. sativa/O. brachyantha* , F_1s of 5 different sizes were chosen which ranged from 0.5 to 2.0 cm and above with a size increment of 0.5 cm per each class. The immature inflorescence bits were inoculated onto MS medium with 2.0 mg l^{-1}/NAA and 1.0 mg l^{-1}/KIN, which was standardised earlier. The results obtained are presented in (Tables 1 and 2).

Of the five different sizes of panicle primordia cultured, maximum callus induction (100%) was noticed when the size ranged from 0.5 to 1.0 cm closely followed by the panicle primordia size ranging from 1.0 to 1.5 cm (99.14%). However, when the panicle primordia is larger than 2.0 cm or smaller than 0.5 cm, the response was very low (78.75 and 68.75% respectively). The effect duration of continuous sub-culturing and their ability to proliferate and redifferentiate was investigated in the calli of *sativa cv. Savitri* × *O. brachyantha* cross. Continuous subcultures at an interval of one month till 12 months are presented in Table 3 (Figures 3). It was observed that, the frequency of redifferentiation was high up to six subculture and started declining thereafter. Highest frequency (93.24%) of redifferentiation was recorded after fifth sub-culture and remained high as 58.82% even after 12th sub-culture.

It was observed that, the frequency of redifferentiation was high up to third subculture and started declining thereafter. Highest frequency (90%) of redifferentiation was recorded after third subculture.

Table 2. Effect of size of explants on callus induction efficiency of immature inflorescence.

Primortial panicle (*)	Number of explants inoculated	Number of callus formed	Induction frequency (in %)	Peak callusing period (days)
PP 1(a)	80	63	78.75	6
PP 2(a)	120	120	100.00	5-7
PP 3(a)	116	115	99.14	5-8
PP 4(a)	90	84	93.33	12
PP 5(a)	112	77	68.75	16

*PP1 = 0.5 cm, PP2 = 0.5-1.0 cm, PP3 =1.0-1.5 cm, PP4 =1.5-2.0 cm, PP5 = above 2.0 cm, (a) = explants were cultured on MS+2.0 mg 2, 4-D + 1.0 mg KIN + 2.0 mg NAA per litre.

Table 3. Effect of subculturing duration on differentiation of calli.

Passage number	Number of Calli transferred	Number of calli redifferentiated	Percentage of redifferentiation
I	40	35	87.5
II	45	35	77.77
III	40	36	90.00
IV	50	40	80.00
V	60	56	93.24
VI	60	52	86.58
VII	40	24	60.00
VIII	50	30	68.18
IX	44	30	45.00
X	40	18	45.00
XI	40	18	45.00
XII	34	20	58.82

DISCUSSION

In the present study, among the wide cross hybrids, only two of the crosses, *O. sativa x O. brachyantha* showed complete sterility and therefore, suitable method was to be adopted for alien gene recombination. From these, one cross, *O. sativa* (*cv. Savitri*) x *O.brachyantha* was selected to study whether somatic cell culture could be helpful in realizing alien genome/chromosome recombination into cultivated rice. Exploration of somaclonal variation for crop improvement has been well demonstrated in rice (Fujiwara and Ojima, 1955; Amemiya et al., 1956; Furuhashi and Yatazawa, 1964; Kawata and Ishihara, 1968; Tamura, 1968). All these authors have used immature embryos, excised roots, stem nodes and intact roots where exogeneous application of 24-D stimulated the production of callus capable of indefinite growth. The advantage of somaclonal variation is that, a wide range of variability with regard to some qualitive and quantitative traits have been observed (Sun et al., 1983; Zhang and Chu, 1984). Zhang and Chu (1986), Indra and Krishnaveni (2009) and Croughan et al. (1986) advocated that, somaclones offer a potentially useful source of genetic variability for varietal improvement in rice. It has also been demonstrated in other cereals and millets (George and Eapen, 1990) that, the spectrum of variability is more in young inflorescence culture than from culture of other explants such as stems seeds and roots (Chen et al., 1985).

In the present study, since all the wide cross hybrids involving wild species having other than AA genomes are sterile and seed progeny from F1s could not be obtained, it was obligatory to use young inflorescence, here in referred to as prirnordial panicle are used as explants source for exploitation of somaclonal variation. Literatures on use of somaclonal variation of realization of recombinants with alien chromosomes are very few. However, Scowcroft et al. (1985) from their experience in wheat and other cereals used wide crosses, *Lolium perenne x L. Lumtiflorum, L. Multiflorum x Festuca arundinaceal, H. 5xplan x S. 5xplan, T. Creassum x H. 5xplan, Saccharum x Zea* and Triticale for somatic cell culture for alien gene introgression. They believed that many of the variatations are due to mutation. Brar and Khush (1986) opined that, somaclonal variation seems to be promising for introgression of alien genes into commercial cultivars. This would be particularly important in wide crosses where chromosomes do not pair. They suggested that, explants of wide crosses, (F1s)

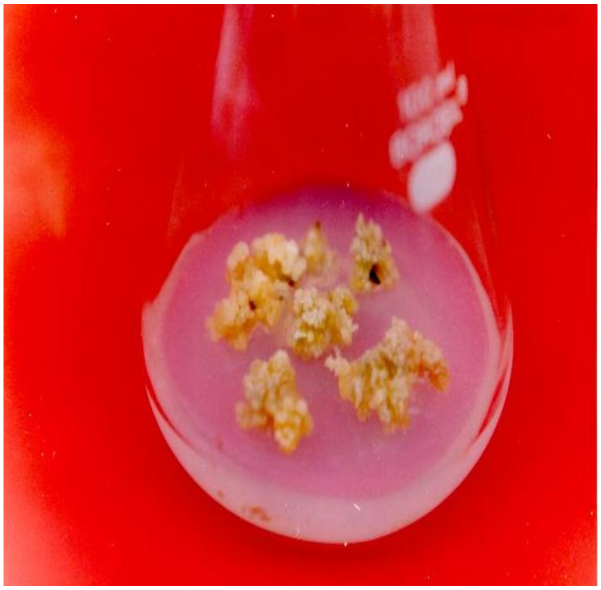

Figure 3. Calli on subculture medium

chromosome addition or substitution lines may enhance the frequency of genetic changes between alien and cultivated genomes. Orton (1980) reported the realization of somaclonal variation from tissue culture in *Hordeum vulgare x H. Jubatum* (a sterile hybrid) where enhanced bibalent formation was there as compared to the original hybrid which was asynaptic. A number of regenerants from that were haploids and Hordeum type. Two of the five haploids exmined expressed a few *H. Jubetum* isozyme bands indicating that some interspecific exchange might have occurred prior to chromosome elimination (Orton, 1980).

Recently, Sudhakar et al. (2009) and Lapitan et al. (1984) obtained regenerants with high degree of chromosome explants66 changes through somatic tissue culture from amphidiploids of wheat x rye hybrids. The karyotype analysis by C-banding of the 10-amphidiploids showed in 3 wheat x rye, in 1 wheat x wheat, translocations, in 7 delitions, in 5 heterochromatin amplification of rye chromosome. It is evident from the foregoing explants what somaclonal variation is one of the useful means to obtain alien gene introgression in cereals and particularly of interest in rice alien gene introgression through wide hybridization. Somaclonal variation using suitable explants could be exploited in three different ways:

(1) Organised plant tissues from plantlets in suitable media which usually contain plant hormones such as auxins and cytokinins. These plantlets are genetically identical with the parents and mutations are relatively rare and if present, as in some species such as potatoes, may be due to cytoplasmic factors or transposons.
(2) The second method is based on the formation of callus tissues and its subsequent utilization for organogenesis and plantlet formation. This method is, however, relatively more difficult than the method using organised tissues. This method is, however, relatively more difficult than the method using organised tissues. This method has been used less frequently but used in some cases as in oil palm. Chromosomal abnormalities occur often, especially on repeated sub-culture of the callus tissue prior to induction of organogenesis. This method is more useful for mutation programmes. The economy in space, time and labour compared to seed mutation makes mutation of the callus culture potentially one of the most attractive methods for the production desired strains for many biotic and abiotic stress and physiological attributes (Jagannathan, 1984).
(3) The third method is also based on initial callus induction from which embryoids and then plantlets are obtained. This method has been so far found applicable to very few species. But the large number of embryoids formed, the development of healthy root system similar to those of seed raised plants makes it an attractive method for exploitation of somaclonal variation. In the present study, since the interest is on induction of chromosome pairing and other abnormalities and mutation, the above second and third ways were effective when F1 primordial panicle was used as explants. Since the advantage of somaclonal variation is the capacity of the tissue to produce callus which yield sufficient variations, it is necessary to have the standardization of media and duration of culture and size of explants. It was observed that, when panicle is at a very young primordial stage where the size is about 0.5 to 1.5 cm, it takes hardly 5 to 7 days for callus initiation. Of the two basic media tested, MS medium supplemented with 2-4-D NAA and kinetin (2 mg L^{-1} 2 mg L^{-1} and 1 mgL^{-1}) was comparatively better for callus growth and proliferation. In this medium callus could be sub-cultured continuously for 12 passages (12 months) without loss of totipotency. However, peak regeneration was between 6 to 8 subculture stages. The present study was to develop an effective protocol for optimum callus induction, duration of culture and size of explants of primordial panicle of inter-genomic hybrid of *O. sativa/O. brachyantha*. The Murashige and Skoog (MS) medium and Chu's N_6 medium supplemented with 2-4-D, NAA and kinetin (2mg L^{-1} 2mg L^{-1} and 1mg L^{-1}) was better for callus growth and proliferation and callus was sub-cultured continuously for 12 passages (12 months) without loss of totipotency. Results indicated that, good plant regeneration could be best effected with 1.5 to 2.0 mg L^{-1} of KIN at fixed level of NAA (at 0.5 mg L^{-1}). These variations via tissue culture will be helpful in alien gene transfer especially in incompatible species of rice in wide hybridization.

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Effect of glyphosate on weed management and grain yield in *Kharif* maize of transgenic stacked and conventional maize hybrids for higher productivity

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A field experiment was carried out at Tamil Nadu Agricultural University, Coimbatore during *kharif* seasons of 2010 and 2011 to study the effect of Glyphosate on weed management and grain yield in *kharif* maize of transgenic stacked and conventional maize hybrid. This investigation was conducted with the following objectives to evaluate the weed control efficiency and crop productivity with K salt of glyphosate formulations under field conditions. Treatments consisted of two transgenic stacked hybrids named 30V92 and 30B11 applied with glyphosate as early post emergence at 900 and 1800 g a.e ha^{-1} during *kharif* season of 2010 and conventional maize hybrids named 30V92 and 30B11 applied with glyphosate by controlled droplet application method at 900, 1350 and 1800 g a.e ha^{-1} during *kharif* season of 2011 compared with non-transgenic counterpart maize hybrids applied with pre emergence atrazine at 0.5 kg ha^{-1} followed by one hand weeding on 40 days after sowing (DAS) with and without insect management. Among the treatments, early POE application of glyphosate at 1800 g a.e ha^{-1} registered lower weed density and higher weed control efficiency in transgenic and non-transgenic maize hybrids at all the intervals. Higher grain yield was registered with post emergence application of glyphosate at 1800 g a.e ha^{-1} in transgenic and non transgenic maize hybrid of 30V92 during both the *kharif* seasons

Key words: Glyphosate, transgenic maize, weed control efficiency, weed index, yield.

INTRODUCTION

Herbicide tolerance has been introduced through genetic modification into a number of crops including maize. The development of crop cultivars with resistance to selected herbicides has the positive impact on agricultural production systems and food safety. Roundup Ready® crop varieties that can be safely treated with glyphosate herbicide to control weeds were first commercialized for soybeans in 1996, for cotton in 1997, and for corn in 1998 (Green et al., 2008). Herbicide tolerance has been introduced through genetic modification into a number of crops including corn. Glyphosate, the active ingredient in the Roundup family (ROUNDUP, ROUNDUP ULTRA AND ROUNDUP READY) were registered trademarks of Monsanto Technology of agricultural herbicides is one of the most widely used herbicides in the world. Glyphosate is highly effective against the majority of annual, perennial grasses, and broad-leaf weeds and has superior environmental and toxicological characteristics such as rapid soil binding and biodegradation as well as extremely low toxicity to mammals, birds, and fish. Glyphosate is a foliar applied, broad spectrum, post emergence herbicide capable of controlling annual,

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perennial grasses and dicotyledonous weeds.

The introduction of glyphosate resistant crops has created new opportunities for the use of effective, non selective herbicides like glyphosate as selective weed control in crop production. Now, it can be used as post emergence herbicide in glyphosate resistant crops (Norsworthy et al., 2001). Roundup Ready corn event NK603 was produced by the stable insertion of two gene cassettes that express 5-enolpyruvylshikimate-3-phosphate synthases from *Agrobacterium* sp. strain CP4 (*CP4 EPSPS*). Corn event NK603 differs from Roundup Ready corn event GA21 that expresses a modified corn EPSPS. While TC1507 maize expresses a Bt insecticidal protein (Cry1F) for control of certain lepidopteron (stem borers) pests and NK603 corn expresses a modified maize 5-enolpyruvylshikimate-3-phosphate synthase enzyme (*CP4 EPSPS*) that confers tolerance to herbicide products containing glyphosate. Post emergence herbicides have been achieved in adequate weed control programmes, due to its broad spectrum of activity, excellent crop safety, convenience and flexibility was reported by Ferrel and Witt (2002).

Post emergence application of glyphosate at 1800 g a.e ha^{-1} in transgenic maize and post emergence control droplet application method of glyphosate at 1800 g a.e ha^{-1} in conventional maize hybrid (30V92) recorded high productivity and profitability. In view of the above facts, an experiment on ''Effect of Glyphosate on weed management and grain yield in *kharif* maize of transgenic Stacked and conventional maize Hybrids'' taken up during *kharif* season of 2010 and 2011 (Tables 1 and 2). Target pests viz., stem borer and cob borer were effectively controlled in transgenic maize hybrids during both the *kharif* seasons.

MATERIALS AND METHODS

Experimental site

Field experiments were laid out during *kharif* seasons of 2010 and 2011 in Eastern bloc farm of Tamil Nadu Agricultural University, located at Coimbatore, India. The geographical location of the experimental site is situated in western agro climatic zone of Tamil Nadu at 11°N longitude and 77°E latitude with an altitude of 426.7 m above MSL and the farm receives the total annual rainfall of 674 mm in 45.8 rainy days. The soil of the experimental site was sandy clay loam in texture (32.48% clay, 18.50% silt and 28.96% coarse sand) with low available nitrogen, medium in available phosphorous and high in available potassium. The soil analysed 260, 11.90 and 490 Kg ha^{-1} of KMnO4-N, Olsen–P and NH_4OAC-K, respectively with EC of 0.16 dSm^{-1}, pH of 8.11 and organic carbon of 0.31%.

Selection of cultivar and sowing

The experiment was laid out in randomized complete block design (RBD) with sixteen treatments and replicated thrice. The gross plot size adopted was (5 × 3.6 m) 18 m^2. The adopted spacing between the rows and plants were 60 and 25 cm respectively. Herbicide tolerant transgenic maize test hybrids namely 30V92, 30B11, and conventional hybrids of 30V92, 30B11, BIO 9681, and COHM5 during the *kharif* season of 2010. Conventional maize hybrids 30V92, 30B11, BIO 9681 and COHM5 were raised during *kharif* season of 2011. After sowing the seed, immediate light irrigation was given to the crop for uniform germination

The herbicides as per the treatments schedule were applied as pre emergence at third day after sowing, glyphosate application at 2 to 4 leaf stage of weeds [20 to 25 days after sowing (DAS) of maize]. Hand operated knapsack sprayer fitted with a flat fan type nozzle (WFN 40) was used for spraying the herbicides adopting a spray volume of 250 L ha^{-1}. The recommended dose of 150:75:75 Kg of NPK ha^{-1} are in the form of urea, single super phosphate and muriate of potash.

RESULTS AND DISCUSSION

Predominant weed flora of the experimental field

Effect on weeds

Weed flora of the experimental field in maize predominantly consist of 12 species of broad leaved weeds, 5 species of grasses and a sedge weed. The dominant among broadleaved weeds were *Trianthema portulacastrum*, *Datura stramonium, Cleome gynandra, Digera arvensis*, *Physallis minima,* and *Corchorus olitorius.* The dominant grass weeds were *Setaria verticillata* and *Cynodon dactylon. C. rotundus* was the only sedge present in the experimental field. With respect to individual weed species during both the years, density of *T. portulacastrum* recorded about 162.80% No.m^{-2} before spraying of glyphosate. Higher weed flora composition registered during both years might be due to adequate rainfall during cropping period which favoured a conducive field environment for weed growth: *T. portulacastrum, D. stramonium, C. gynandra, P. minima, D. arvensis, S. verticillata*, and *C. dactylon.* The results are in line with the findings of (Nadeem et al., 2008) who reported that *T. portulacastrum, D. arvensis* were the most common weeds which compete with maize and assimilate faster biomass than maize.

Weed control rating in maize

Weed control rating score was done at 7, 15, and 21 days after sowing (DAS) in transgenic maize hybrids with POE application of glyphosate at various rates of application. At 7 DAS, moderate control of broad leaved weeds and grass (score = 6) and poor to deficient control of sedges (score = 3) were observed with glyphosate at 900 g a.e ha^{-1}. Satisfactory control of broad leaved weeds and grass (score = 7), deficient control of sedges (score = 4) were observed under glyphosate at 1800 g a.e ha^{-1}. Glyphosate at 900 and 1800 g a.e ha^{-1} at 15 DAS resulted in good control of broad leaved and grass weeds (score = 8), moderate control of sedges (score = 6) (Table 2). Whereas at 21 DAS, complete control of broad leaved weeds and grass (score = 10), good control of sedges (score = 9) were noticed under glyphosate at 1800 g a.e ha^{-1}. Satisfactory control of sedges was observed

Table 1. Weed control rating in transgenic maize – *kharif* season of 2010.

Treatment	7 DAS			15 DAS			21 DAS		
	BLW	Grass	Sedge	BLW	Grass	Sedge	BLW	Grass	Sedge
T_1 - 30V92 HR Glyphosate at 900 g a.e ha^{-1}	6.0	6.0	3.0	8.0	7.0	6.0	10.0	8.0	8.0
T_2 - 30V92 HR Glyphosate at 1800 g a.e ha^{-1}	7.0	7.0	4.0	9.0	8.0	6.0	10.0	10.0	9.0
T_4 - 30B11HR Glyphosate at 900 g a.e ha^{-1}	6.0	6.0	3.0	7.0	7.0	6.0	9.0	9.0	8.0
T_5 - 30B11HR Glyphosate at 1800 g a.e ha^{-1}	7.0	7.0	4.0	9.0	8.0	6.0	10.0	10.0	9.0

Data not statistically analysed BLW: Broad leaved weeds.

Table 2. Weed control rating in non transgenic maize – *kharif* season of 2011.

Treatment	7 DAS			15 DAS			21 DAS		
	BLW	Grass	Sedge	BLW	Grass	Sedge	BLW	Grass	Sedge
T_1 - 30V92 POE Glyphosate at 900 g a.e ha^{-1}	6.0	6.0	3.0	7.0	7.0	5.0	9.0	9.0	8.0
T_2 - 30V92 POE Glyphosate at 1350 g a.e ha^{-1}	7.0	7.0	4.0	8.0	8.0	6.0	10.0	10.0	9.0
T_3 - 30B11 POE Glyphosate at 1800 g a.e ha	8.0	7.0	4.0	8.0	8.0	6.0	10.0	10.0	9.0
T_4 - 30B11 POE Glyphosate at 900 g a.e ha^{-1}	6.0	6.0	3.0	7.0	7.0	5.0	9.0	9.0	8.0
T_5 - 30B11 POE Glyphosate at 1350 g a.e ha^{-1}	7.0	7.0	4.0	8.0	8.0	6.0	10.0	10.0	9.0
T_6 - 30B11 POE Glyphosate at 1800 g a.eha^{-1}	8.0	7.0	4.0	8.0	8.0	6.0	10.0	10.0	9.0

Data not statistically analysed BLW: Broad leaved weeds.

with glyphosate at 900 g a.e ha^{-1}.In non-transgenic maize hybrids at 3 DAS, deficient to moderate control of broad leaved weeds, poor to deficit control of grass and poor control of sedge (scoring = 5, 3, and 2), respectively were observed with glyphosate application at 900 g a.e ha^{-1}. Whereas, POE application of glyphosate at 1350 and 1800 g a.e ha^{-1} was observed a deficient to moderate control of broad leaved weeds and grasses (score = 5), poor control of sedge (score = 2). Glyphosate at 1350 and 1800 g a.e ha^{-1} at 15 DAS resulted in good control of broad leaved and grass weeds (score = 8), moderate control of sedges (score = 6). Whereas, at 21 DAS, complete control of broad leaved weeds and grass (score = 10) good control of sedges (score = 9) were noticed under glyphosate at 1350 and 1800 g a.e ha^{-1} (Table 2).

Weed density

The weed control methods effectively controlled the density of all the weeds under both transgenic and non-transgenic maize hybrids at different stages of crop growth as compared to unweeded control. During *kharif* season of 2010, lower weed density was achieved under non transgenic maize hybrid BIO 9681 and 30B11 with pre emergence application of atrazine at 0.5 Kg ha^{-1} followed by hand weeding at 20 DAS. Relatively, a higher density was observed under unweeded checks and transgenic maize before imposing post emergence application of glyphosate. Atrazine effectively controlled majority of broad leaved and grassy weeds at earlier stages of maize growth. Mundra et al. (2003) reported that, application of atrazine at 0.5 kg ha^{-1} as pre-emergence fb inter cultivation at 35 DAS in maize significantly reduced the total weed density (Table 3).

At 40 and 60 DAS, lower weed density (2.04 and 2.35) was observed under transgenic maize hybrid 30V92 with post emergence application of glyphosate at 1800 g a.e ha^{-1} resulted in effective control of broad leaved weeds, grasses and sedges due to its broad spectrum action (Wilcut et al., 1996). This may due to more impressive control of broadleaved weeds like *T. portulacastrum, D. stramonium, C. gynandra* and *P. minima*. Foliar application of glyphosate was readily and rapidly translocated throughout the actively growing aerial and underground portions at active growing stage of broadleaved weeds might have blocked the 5-Enulpyruvate shikimate-3-phosphate synthase enzyme and arrest the amino acid synthesis which led to complete control (Summons et al., 1995). During kharif season of 2011, post emergence controlled droplet application of glyphosate at conventional maize hybrid of 30V92 at 1800 g a.e ha^{-1} (1.84 Nos m^{-2}) observed lesser total weed density at 40 DAS. Thus, glyphosate effectively controlled a broad spectrum of annual and perennial grasses, sedges and broadleaved weeds could be due to increased translocation of glyphosate inside the plant tissues Suwunnamek and Parker (1975) (Table 4).

Effect on crop

High persistence nature of weeds was attributed to their ability of high seed production and seed viability. Post

Table 3. Effect of glyphosate application on total weed density in transgenic maize.

Treatment	Total weed density (No. m^{-2}) Kharif season of 2010		
	20 DAS	40 DAS	60 DAS
T_1 - T.30V92 HR Glyphosate at 900 g a.e ha^{-1}	15.43 (236.22)	2.78 (5.75)	3.41 (9.63)
T_2 - T.30V92HR Glyphosate at 1800 g a.e ha^{-1}	15.33 (233.08)	2.04 (2.15)	2.35 (3.52)
T_3 - T.30V92HR (Weedy check)	15.74 (245.60)	14.32 (202.93)	13.81 (188.75)
T_4 - T.30B11HR Glyphosate at 900 g a.e ha^{-1}	15.78 (246.89)	3.31 (8.98)	3.84 (12.74)
T_5 - T.30B11HR Glyphosate at 1800 g a.e ha^{-1}	16.06 (256.07)	2.55 (4.50)	3.06 (7.35)
T_6 - T.30B11HR (Weedy check)	15.81 (248.10)	14.54 (209.43)	14.42 (205.99)
T_7 - N.T.30V92 PE atrazine 0.5 kg ha^{-1} + HW+ IC	7.99 (61.85)	7.81 (59.00)	5.79 (31.48)
T_8 - N.T.30V92 No WC and only IC	15.45 (236.55)	13.64 (183.99	12.74 (160.36)
T_9 - N.T.30V92 No WC and no IC	16.05 (255.75)	14.37 (204.37)	14.38 (204.69)
T_{10} - N.T.30B11 PE atrazine 0.5 kg ha^{-1} + HW+ IC	7.55 (55.00)	8.14 (64.34)	5.87 (32.43)
T_{11} - N.T.30B11No WC and only IC	15.51 (238.44)	13.58 (182.38)	13.12 (170.11)
T_{12} - N.T.30B11 No WC and no IC	16.25 (262.00)	15.05 (224.47)	15.05 (224.57)
T_{13} - BIO9681 PE atrazine 0.5 kg ha^{-1}+ HW + IC	7.15 (49.14)	7.52 (54.58)	5.96 (33.49)
T_{14} - BIO9681No WC and no IC	14.69 (213.70)	13.85 (189.93)	14.52 (208.94)
T_{15} - CoHM5 PE atrazine 0.5 kg ha^{-1}+ HW + IC	7.83 (59.37)	8.32 (67.3)	6.20 (36.44)
T_{16} - CoHM5 No WC and no IC	16.38 (266.19)	15.24 (230.37)	15.79 (247.44)
SEd	1.34	1.11	1.06
CD(P = 0.05)	2.74	2.27	2.17

T.30V92-Transgenic stacked 30V92, N.T.30V92-Non transgenic 30V92, T.30B11– Transgenic30B11, N.T.30B11-non transgenic 30B11, HW-hand weeding, IC-insect control, WC-weed control.

Table 4. Effect of glyphosate application on total weed density in non transgenic maize.

Treatment	Total weed density (No. m^{-2}) Kharif season of 2011		
	20 DAS	40 DAS	60 DAS
T_1 - N.T.30V92 POE Glyphosate at 900 g a.e ha^{-1}	16.61 (273.97)	4.11 (14.89)	4.61 (19.29)
T_2 - N.T.30V92 POE Glyphosate at 1350 g a.e ha^{-1}	16.25 (262.05)	2.91 (6.45)	3.69 (11.62)
T_3 - N.T.30V92 POE Glyphosate at 1800 g a.e ha^{-1}	16.52 (271.05)	1.84 (1.4)	2.85 (6.10)
T_4 - N.T.30B11 POE Glyphosate at 900 g a.e ha^{-1}	16.41 (267.29)	4.32 (16.65)	4.84 (21.41)
T_5 - N.T.30B11 POE Glyphosate at 1350 g a.e ha^{-1}	16.60 (273.46)	3.16 (8.01)	4.16 (15.27)
T_6 - N.T.30B11 POE Glyphosate at 1800 g a.e ha^{-1}	16.93 (284.57)	2.23 (2.99)	3.36 (9.32)
T_7 - 30V92 PE atrazine 0.5 kg ha^{-1} + HW+ IC	7.37 (52.27)	8.78 (75.16)	6.81 (44.43)
T_8 - 30V92 No WC and only IC	16.35 (265.46)	14.83 (217.99)	14.58 (210.68)
T_9 - 30V92 No WC and no IC	17.03 (287.95	15.49 (238.01)	15.35 (233.48)
T_{10} - 30B11 PE atrazine 0.5 kg ha^{-1} + HW+ IC	8.10 (63.62)	9.36 (85.67)	7.47 (53.85)
T_{11} - 30B11No WC and only IC	15.74 (245.85)	15.13 (226.78)	14.97 (222.00)
T_{12} - 30B11 No WC and no IC	17.12 (291.03)	15.91 (251.15)	16.06 (255.96)
T_{13} - BIO9681 PE atrazine 0.5 kg ha^{-1} + HW+ IC	7.95 (61.21)	8.84 (76.16)	6.86 (45.02)
T_{14} - BIO9681No WC and no IC	16.56 (272.3)	15.53 (239.32)	15.32 (232.73)
T_{15} - CoHM5 PE atrazine 0.5 kg ha^{-1} + HW+ IC	8.49 (70.03)	9.82 (94.53)	7.20 (49.79)
T_{16} - CoHM5 No WC and no IC	17.21 (294.18)	17.10 (290.48)	16.98 (286.30)
SEd	1.41	1.10	1.05
CD(P = 0.05)	2.89	2.26	2.14

T_1-T_{16}- Non Transgenic maize hybrids ; HW-Hand weeding; IC-Insect control; WC-Weed control.

emergence herbicides have been achieved adequate weed control programmes. During both years of study, among

Table 5. Effect of glyphosate application on weed control efficiency, weed index and grain yield of transgenic maize.

Treatment	*Kharif* season of 2010			
	WCE (%), weed index (%), yield (kg ha^{-1})			
	20 DAS	40 DAS	90 DAS	90 DAS
T_1 - T.30V92 HR Glyphosate at 900 g a.e ha^{-1}	0.00	98.56	9.09	11.10
T_2 - T.30V92HR Glyphosate at 1800 g a.e ha^{-1}	0.00	99.53	0.00	12.21
T_3 - T.30V92HR (Weedy check)	0.00	0.00	27.60	8.84
T_4 - T.30B11HR Glyphosate at 900 g a.e ha^{-1}	0.00	97.72	10.15	10.97
T_5 - T.30B11HR Glyphosate at 1800 g a.e ha^{-1}	0.00	98.97	1.88	11.98
T_6 - T.30B11HR (Weedy check)	0.00	0.00	25.30	9.12
T_7 - N.T.30V92 PE atrazine 0.5 kg ha^{-1} + HW+ IC	80.28	72.57	16.21	10.23
T_8 - N.T.30V92 No WC and only IC	0.00	14.66	31.77	8.33
T_9 - N.T.30V92 No WC and no IC	0.00	0.00	38.41	7.52
T_{10} - N.T.30B11 PE atrazine 0.5 kg ha^{-1} + HW+ IC	79.66	70.33	20.06	9.76
T_{11} - N.T.30B11No WC and only IC	0.00	11.92	32.84	8.20
T_{12} - N.T.30B11 No WC and no IC	0.00	0.00	39.80	7.35
T_{13} - BIO9681 PE atrazine 0.5 kg ha^{-1}+HW+ IC	77.27	68.73	34.47	8.00
T_{14} - BIO9681No WC and no IC	0.00	0.00	49.87	6.12
T_{15} - CoHM5 PE atrazine 0.5 kg ha^{-1}+HW+ IC	79.28	68.56	39.96	7.33
T_{16} - CoHM5 No WC and no IC	0.00	0.00	58.39	5.08
SEd	-	-	-	0.41
CD(P = 0.05)	-	-	-	0.84

T.30V92-Transgenic stacked 30V92 , N.T.30V92- non transgenic 30V92,T.30B11 – transgenic30B11, N.T.30B11-non transgenic 30B11, HW-hand weeding, IC-insect control; WC-weed control.

the weed control treatments, post emergence application of glyphosate at 1800 g a.e ha^{-1} in transgenic corn hybrid recorded higher grain yield of 12.21 t ha^{-1} this was 36.64 % higher than the unweeded check plot of transgenic 30V92 during *kharif* season of 2010 (Table 5). Whereas during *kharif* season of 2011, post emergence controlled droplet application of glyphosate at 1800 g a.e ha^{-1} in conventional maize hybrid of 30V92 resulted in higher grain yield of 11.23 t ha^{-1} (Table 6). This was 44.79% higher than the unweeded check plot of conventional maize hybrid. This could be the achieved control of weeds with non selective, translocated herbicide, provided the favourable crop growth environment at the establishment stage of the crop itself by minimizing the perennial and annual weeds and increased the seed and stalk yields (Tharp et al., 1999). This might be due to the fact that, the perennial weeds like *Cyperus rotundus*, *C. dactylon*, troublesome broadleaved weeds like *T. portulacastrum* weeds were effectively controlled and might increase the maize yield may be due to better light utilization of narrow row zone and faster canopy closure (Murphy et al., 1996). This might be also improved yield components viz., higher number of grains per cob, grain weight per plant and test weight. This improvement in turn was due to improved growth attributes such as higher total dry matter production and distribution in different parts, higher leaf area index. Thus, the improvement in crop growth and yield components was the consequence of lower crop weed competition, which shifted the balance in favour of crop in the utilization of nutrients, moisture, light and space. These results are in conformity with the findings of Kamble et al. (2005).

Maize grain yield of POE application of glyphosate at 1800 g a.e ha^{-1} in transgenic 30V92 (T_2) was taken as basis to work out the weed index (WI) during *kharif* season of 2010. In transgenic maize hybrids, among the different rates of glyphosate, 900 g a.e ha^{-1} recorded lesser weed index of (9.09 and 10.15 per cent) in transgenic 30V92 (T_1) and 30B11 (T_4) respectively. In non-transgenic maize hybrids, PE application of atrazine 0.5 kg ha^{-1} + HW in 30V92 recorded lesser weed index (16.21%) compared all other non-transgenic hybrids with same treatment. During *kharif* of the 2011 among the different rates of glyphosate by controlled droplet application method of glyphosate at 1350 g a.e ha^{-1} recorded lower weed index of 7.75 and 15.23% in non transgenic maize hybrids of 30V92 (T_2) and 30B11(T_5). It was followed by POE application of glyphosate at 900 g a.e ha^{-1} in both non transgenic maize hybrids *viz*., 30V92 and 30B11. However, in PE application of atrazine at 0.5 kg ha^{-1} *fb* HW in 30V92 (T_7) maize hybrid recorded least weed index compared all other non-transgenic hybrids with same treatment. Unweeded check plots resulted in higher weed index and performed poorly during both the years.

Weed control efficiency which indicates the comparative magnitude of reduction in weed dry matter, was highly influenced by different weed control treatments. Pre emergence application of atrazine at 0.5 Kg ha^{-1} followed

Table 6. Effect of glyphosate application on weed control efficiency, weed index and grain yield of transgenic maize.

Treatment	*Kharif* season of 2011			
	WCE (%), weed index (%), yield (Kg ha^{-1})			
	20 DAS	40 DAS	90 DAS	90 DAS
T_1 - N.T.30V92 POE Glyphosate at 900 g a.e ha^{-1}	5.14	96.15	9.09	9.12
T_2 - N.T.30V92 POE Glyphosate at 1350 g a.e ha^{-1}	14.29	97.66	0.00	10.36
T_3 - N.T.30V92 POE Glyphosate at 1800 g a.e ha^{-1}	8.73	99.14	27.60	11.23
T_4 - N.T.30B11 POE Glyphosate at 900 g a.e ha^{-1}	21.41	95.86	10.15	8.25
T_5 - N.T.30B11 POE Glyphosate at 1350 g a.e ha^{-1}	14.16	97.17	1.88	9.52
T_6 - N.T.30B11 POE Glyphosate at 1800 g a.e ha^{-1}	11.15	98.87	25.30	10.39
T_7 - 30V92 PE atrazine 0.5 kg ha^{-1} + HW+ IC	82.26	68.96	16.21	8.72
T_8 - 30V92 No WC and only IC	13.97	10.25	31.77	7.40
T_9 - 30V92 No WC and no IC	0.00	0.00	38.41	6.20
T_{10} - 30B11 PE atrazine 0.5 kg ha^{-1} + HW+ IC	80.03	65.71	20.06	8.01
T_{11} - 30B11No WC and only IC	13.57	8.31	32.84	6.80
T_{12} - 30B11 No WC and no IC	0.00	0.00	39.80	6.22
T_{13} - BIO9681 PE atrazine 0.5 kg ha^{-1} + HW+ IC	78.97	63.82	34.47	7.10
T_{14} - BIO9681No WC and no IC	0.00	0.00	49.87	5.60
T_{15} - CoHM5 PE atrazine 0.5 kg ha^{-1} + HW+ IC	73.19	61.68	39.96	6.10
T_{16} - CoHM5 No WC and no IC	0.00	0.00	58.39	4.80
SEd	-	-	-	0.80
CD(P = 0.05)	-	-	-	1.64

T_1-T_{16}- Non Transgenic maize hybrids, HW-Hand weeding; IC-Insect control; WC-Weed control.

by hand weeding recorded higher weed control efficiency of 80.28% in non transgenic maize hybrid 30V92 at 20 DAS. Whereas at 40 DAS, after spraying of herbicide, higher weed control efficiency of 99.53% was recorded in glyphosate at 1800 g a.e ha^{-1} followed by 30B11 was observed 98.97% during *kharif* season of 2010 (Table 5). Whereas, during *kharif* season of 2011, higher weed control efficiency was observed with glyphosate at 1800 g a.e ha^{-1} in conventional maize hybrid of 30V92 registered maximum weed control efficiency of 99.14% owing to the fact that registered the lesser weed density (Table 6).

Different rates of glyphosate under transgenic maize hybrids recorded more than 90% control efficiency at 40 DAS. Whereas, at the same time PE application of atrazine in non transgenic hybrids recorded only 70 to 80. This might be due to the application of glyphosate which did not allow weeds to accumulate sufficient biomass and ultimately resulted in higher weed control efficiency. Properly timed sequential application of glyphosate was effective in season-long control of common waterhemp (*Amaranthus rudis*), giant foxtail (*Setaria faberi*), velvetleaf (*Abutilion theophrasti*), common cocklebur (*Xanthum strumarium*) and common lambsquarters (*Chenopodium album*) at levels more than 90 per cent through the season was reported by (Hellwig et al., 2002).

Conclusion

The results of this experiment revealed that, lesser weed dry weight and higher weed control efficiency were achieved with post emergence application of glyphosate at 1800 g a.e ha^{-1} in transgenic and post emergence controlled application of glyphosate at 1800 g a.e ha^{-1} in non transgenic hybrid of 30V92 during *kharif* season of 2010 and 2011 seasons, respectively. These enhanced the productivity of kharif maize resulting in higher economic returns.

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Fabrication and characterisation of nanoporous zeolite based N fertilizer

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A laboratory study was undertaken to improve the nitrogen (N) use efficiency of urea using microporous natural zeolite (Z) and nanoporous zeolite (NZ) as substrate. The fertilizer composite was prepared under ambient conditions by impregnation urea in adsorbents. Z and nanoporous-zeolite measuring a dimension of 794, 87 nm were used for this study. The commercial urea fertilizer and adsorbents were blended or fused at varying w/w ratios of 1:1 to 1:10 using simple liquid immersion with hydrothermal technique. The 1:1 ratio of natural zeolite: urea and NZ: urea registered the highest total N content of 18.5 and 28%, respectively. The adsorbents and fabricated fertilizers such as zeourea (ZU) and nano-zeourea (NZU) of 1: 1 ratios were characterized using particle size analyzer, zeta potential, X-ray diffraction, FT-IR, Raman spectroscopy, and SEM with EDS besides release pattern of N. The data revealed that, the N release from the urea blended with NZ (1:1) was up to 48 days while the conventional Z - urea (1:1) mix was up to 34 day and the N release ceased to exist in urea within 4 days under ambient conditions. This suggests that, nanoporous zeolite based on N fertilizer (NZU) can be used as alternate strategy to improve the N use efficiency in crop production systems.

Key words: Nanoporous zeolite, Natural zeolite, Nano-fertilizers, Nitrogen, Slow release N fertilizers.

INTRODUCTION

Despite the fact that the atmosphere carries 78% of Nitrogen (N) and the soil organic matter possesses 98% N, still available N status of more than 90% of the arable soils are found deficient. Such low N status is attributed to the losses of N due to high rate of mineralization, volatilization, leaching, and denitrification. To prevent the problems arising from the high solubility of many N fertilizers and their potential vulnerability to leaching, especially in the nitrate form, a range of slow-release fertilizers (SRFs) and controlled-release fertilizers (CRFs) have been developed (Shaviv, 2000; Subramanian and Tarafdar, 2011). N should be continuously available throughout the growing season to provide optimum yield and quality. To develop N fertilizers with controlled release characteristics, the adsorbents zeolite, halloysite, montmorillonite, and bentonite nanoclays were used (Sharmila, 2010) and the purification of nanoclay is time consuming and costly affair excluded zeolite (Rs.12/- per kg). Zeolite pores can hold N much higher than other nanoclay. The present study is one of the pioneer

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Abbreviations: Z, natural zeolite, **NZ,** nanoporous, **ZU,** zeolite zeourea, **NZU,** nano-zeourea.

works to reduce the soil and water pollution by improving nutrient use efficiency (NUE).

Zeolites are abundant in nature and occurring along with low grade metamorphic rocks of hydrous alumina silicate mineral. They are a series of microporous ordered crystals with complex pores and are microporous, mesoporous, and nanoporous. Ions can be immobilized on zeolites by two mechanisms viz., ion exchange and chemisorption. Weak and strong chemical bond creation between ions and zeolite plays a major role of nutrient release and availability in soil solution. Natural zeolite (Z) and nanoporous zeolite (NZ) consists approximately 30 to 40% of channels of 0.4 to 1 nm pore diameter. This porespace (35 to 40%) would be used for loading N and Potassium (k) (Bansiwal et al., 2006). Utilizing preferential ion exchange property of zeolite helps to reduce and avoid the contamination of natural resources (Wei et al., 2011). Mesoporosity, nanoporosity and high surface area can be used for loading nutrients and it can be used as a slow release and novel nano-fertilizer.

The dominant process in N adsorption on these zeolites is influenced by the electric field created by the charge-balancing cations in the pores and by hydrogen-bonding with surface. In the recent years, NZ have attracted considerable attention due to the expectation of their unique surface properties, shorter diffusion pathlengths and higher cation exchange capacity (CEC) (Ramesh et al., 2010). Assessment of micro and nano-scale level of urea interactions with Z and NZ will provide valuable information about adsorption property, which will indirectly help in improving nutrient use efficiency and reduces loss of nutrients. Z has capacity to trap ammonia and retains N in the rooting zone of plants. The simplest method to impregnate N is to physically mix the urea in solution with the adsorbents support under given temperature, stirring and time conditions, followed by solvent removal by evaporation or filtration (Chang, 1997). Nano-fertilizers and nano composites can be used to control the release of nutrients from the fertilizer granules so as to improve the nutrient use efficiency while preventing the fixation or loss of nutrients to the environment (Chang, 1997). The present study hypothesize that, N derived from urea fortified in zeolite adsorbent facilitates slow and regulated release of N that may serve as a strategy to evolve slow release fertilizer with improved use efficiency.

MATERIALS AND METHODS

Fabrication of nanoporous zeolite based N fertilizer

A laboratory experiment was conducted to fabricate N fertilizers using Z and NZ and study the nutrient release pattern at the Tamil Nadu Agricultural University, Coimbatore during 2012. Z (clinoptilolite) was purchased from GM Chemicals, Ahmedabad and was used for this study. The Z or NZ based fertilizers were fabricated under ambient conditions by impregnation and simple liquid immersion hydrothermal technique (Chang, 1997). Adsorbents Z and NZ were preheated (150°C for 3 days) in a hot air oven for efficient adsorption of N. Required amount of urea crystals were mixed with distilled water by weight and continuous shaking. The urea solution was heated at 115°C till it changed from the crystal structure to liquid and then the required quantity of adsorbents (Z or NZ) were added at different ratios of 1:1, 1:2, 1:3, 1:5, and 1:10 on w/w basis. The prepared mixer was heated continuously till the liquid fertilizer is completely absorbed on the Z or NZ. Cooling down the mixer with air (80ºC) and it gives to crystal structure and it became a solid inside. Constant cooling (50ºC) of solid material and add polymer (carboxyl methyl cellulose sodium salt) with continuous mixing (approximately 10% of the weight of the Z or NZ). The polymer reduces contact and release nutrient as slow. Air dried the mixture and powdered for further study. Ten different range of fertilizers of urea loaded Z and NZ (1:1, 1:2, 1:3, 1:5, and 1:10) were prepared with continuous shaking. The total N content of fabricated fertilizers was estimated (Muthuvel and Udayasoorian, 1999). Detailed physio-chemical properties of Z and NZ were given (Table 1).

Characterisation

The adsorbent (Z, NZ) and fabricated fertilizers (ZU, NZU) were characterized using particle size analyser (PSA), X-ray diffraction (XRD), Fourier-transform infrared spectroscopy (FT-IR), Raman Spectroscopy,Scanning electron microscopy (SEM) and Energy dispersive X-ray spectroscopy (EDS) estimated as per standard procedure (Das and Ansari 2009).

Particle size distributions and Zeta potential measurements

Both adsorbents (Z, NZ) and fertilizers (ZU, NZU) were sieved through 40 µm sieves and the particle sizes were measured using PSA (Horiba Scientific Nanopartica SZ-100). About 0.5 mg of sample was dispersed in 20 ml of water and sonicated for 30 min with 10 seconds on-off cycle. The samples were dispersed and a drop of 0.02% Tween-80 was added in water. The size measurements were performed at 25°C at 90º/173º scattering angle.

X-ray diffraction patterns

The X-ray diffractograms have been recorded on Powder XRD (Bruker D8 Advance Powder X-ray Diffractometer, Germany). The machine exploits Cu-Kα radiation (0.154 nm) for measuring the crystalline nature of atoms in the material (Toraya, 1986). The diffractograms were recorded in the range of 2θ = 10-80 degrees at a scanning speed of 0.080 and step times 1s at room temperature 25ºC.

FT-IR spectra and raman shifts

The adsorbents and fertilizers were finely ground and mixed with KBr to 0.1% and then pressed into pellets prior to measure the IR spectra (Byler et al., 1991). Each pellet of the sample weighed approximately 2 mg. The spectra of the samples were determined at 2 cm^{-1} resolution, 0.44s/scan on a using Shimadzu Model-FTIR. Raman Shifts were measured in powdered adsorbents and fertilizers using Raman Spectroscopy (R-3000 QE TM). The laser wavelength was 785 nm produced by a diode solid state laser operated at 100 mW at the source (Frost, 1997). The machine was set in the spectral range of 200 to 2000 cm^{-1}. All graph were prepared using Microcal origin 6.0 software.

Table 1. Physio-chemical properties of natural zeolite and nanoporous zeolite.

Property	Natural zeolite	Nanoporous zeolite
pH (1: 6.25ml ratio)	9.6	8.14
EC_e (dSm^{-1}) (saturated paste)	0.17	0.06
Moisture (%)	10	12
Bulk density (Mg m^{-3})	0.57	0.50
Particle density (Mg m^{-3})	0.66	0.39
Pore space (%)	34	45
Total organic carbon (%)	1.9	1.03
Total nitrogen (%)	0.02	0.03
Total phosphorus (%)	0.06	0.02
Total potassium (%)	0.09	0.02
Calcium* (%)	5.25	-
Magnesium* (%)	6.03	-
Silica* (%)	4.78	1.49
Aluminium* (%)	1.02	1.59
CEC(cmol(p^+) Kg^{-1})	100	106
Inorganic carbon (%)	28	45
*EDS data		

Scanning electron microscope (SEM) with EDS

Surface morphology and cross sectional analysis was conducted using SEM (FEI Quanta 250). The samples were prepared onto adhesive carbon tape on an Aluminum stub. Varying magnifications were used to compare the structure and surface characteristics of the zeolite. The images were taken at an accelerating voltage of 20 kV. Surface element analysis was also conducted simultaneously with the SEM at the same surface locations using EDS. The EDS can provide rapid quantitative with adequate standards, semi-quantitative analysis of elemental composition with a sampling of 1 to2 µm.

Nutrient Release Pattern

To study nutrient release pattern, the percolation reactor was designed (Bansiwal et al., 2006). The reactor consisted of a glass cylinder (internal diameter = 2.5 cm, height = 15 cm) with 4 pore holes and experiment was conducted under ambient temperature. 10 g of soil was homogenised with adsorbents (Z, NZ) and fertilizers (ZU, NZU and Urea alone) which comprised 6 treatments along with control (soil alone). The 50 ml of deionized ultrapure water was added to the above from 1 to 50 days. Solutions were collected to determine ammonium and nitrate ions as per water quality standard protocol (Tandon, 1993). By this technique, comparative study of slow release tendency for adsorbents and fertilizers would be estimated, to develop a novel fertilizer.

Statistical analysis

All triplicate data were analysed using the analysis of variance (ANOVA). The Student's t-test was used with statistical significance for all tests were considered as $P < 0.05$.

RESULTS AND DISCUSSION

Nitrogen content of fertilizers

The total N contents of the urea alone (46%), fertilizer mixtures of urea and Z ratio at 1:1, 1:2, 1:3, 1:5, 1:10 were 18.5, 11.5, 9.0, 4.2, and 0.5% (Figure 1). While the same set of fertilizer mixture ratios with NZ, the total N content increased to 28.0, 26.3, 13.5, 5.0 and 0.7%, respectively. The data clearly indicated that, the N contents of NZ based fertilizer mixture were consistently higher regardless of urea: Z ratios. The highest N content of 28.0% was recorded in 1:1 ratio (urea: NZ) which was significantly higher than conventional urea: Z mixture at the same ratio (18.5%).

The data suggest that, the size reduction in adsorbent (natural zeolite) from micro to nano-dimension coincided with an increase in N content by 33.3%. Such phenomenal increase may be attributed to the extensive surface area exhibited by nano-based formulations that facilitates adsorption processes. The results are in conformity with the observations of reported literatures by Chang (1997), Behnassi et al. (2011) and Kerr (1986) on nano-mediated nutrient release from smart customized fertilizers. It is well understood that, the unique property of nanotechnology is the high surface - mass ratio. Z possesses a surface of 648 m^2 g^{-1} while the same zeolite in nano-dimension measures 1126 m^2 g^{-1}. Thus, the extensive surface area would have helped the NZ to retain N which reflected on the N content of the fertilizer formulation (Taufiqurrahmi et al., 2011) and NZ with urea solution complex reduce the urea hydrolysis rate (Komarneni, 2009; Wang et al., 2010).

Characterisation

The results on particle size distribution (PSD) with zeta potential of adsorbents (Z, NZ) and fertilizer formulations of 1:1 ratio (ZU, NZU) are given (Table 2). The mean

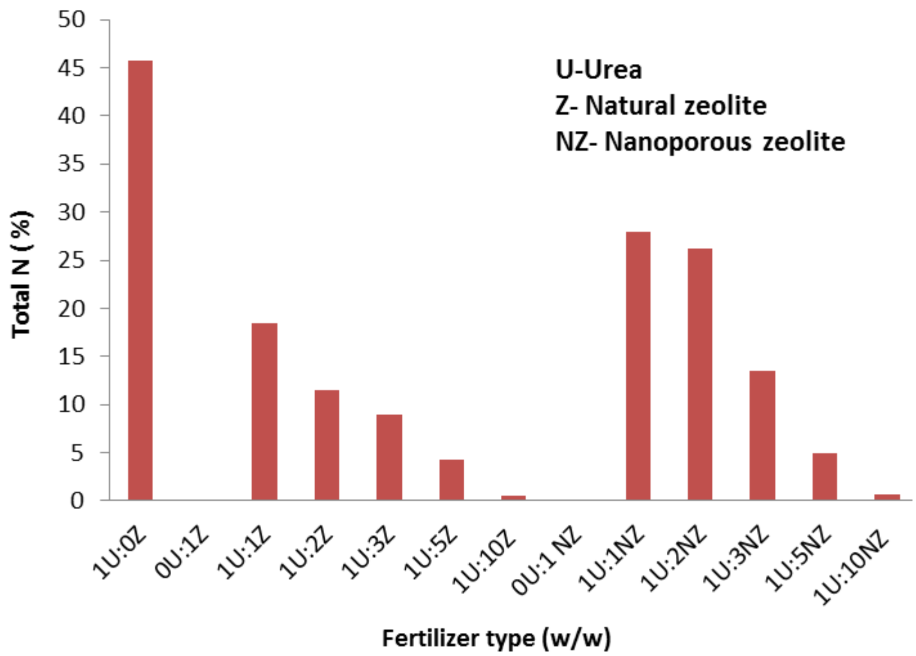


Figure 1. Evaluation of total nitrogen (%) in different adsorbent and fabricated fertilizers.

Table 2. Average particle size distribution (PSD), zeta potential of natural zeolite, nanoporous zeolite and fertilizer formulations at 1:1 ratio.

Source	PSD (nm)	Zeta potential (mV)
Natural zeolite (Z)	794	-45.9
Zeourea (ZU) (1:1)	1120	-49.4
Nanoporous zeolite (NZ)	87	-50.4
Nano-zeourea (NZU)(1:1)	366	-64.3

data on PSD indicated that, particle sizes of micro-zeolite (1120) and NZ (87) had increased when N is impregnated into the adsorbent of 1:1 ratio 1120 and 366 nm respectively (Figure 2). The results are in agreement with an observation which has suggested the reduction size of zeolite from 1000 nm to 3040 nm on high energy ball milling for more than 6 h (Sharmila, 2010). This top down approach has facilitated extensive surface area for adsorption of cationic nutrients and anionic nutrients on surface modification of the zeolite with cationic surfactant. Our study has clearly shown that the zeta potentials of the particles in the range of -30 to -65 indicating the stability (Figure 3). The Zeta potential indicates the stability of sample and minimal aggregation of fabricated fertilizers.

The XRD patterns of the sample showed the maxima at 2θ = 30.8, 22.30, 26.64, and 22.32 for zeolite alone, zeourea (1:1), NZ alone, and nano-zeourea (1:1) that corresponded to *d* spacing = 2.89, 3.97, 3.33, and 3.96 Aº respectively (Figure 4a to d). On comparing the data of adsorbents and fabricated fertilizers with those of loaded N, it is observed that, they closely resemble with each other, indicating that the structural integrity of material is retained after loading of N (Toraya, 1986).

The FT-IR spectrum of finely ground naturally occurring natural zeolite, zeourea, NZ, and nanozeourea has shown the functional groups (Figure 5a to d) and were studied. Zeourea yielded the spectra of 817 for nitrate ion, 1242 for C-N and 1512, 1651 $cm^{-1}$for N-H strectching bands. Nano-zeourea yielded the spectra of 1288 for C-N and 1512, 1561cm^{-1} for N-H strectching bands. Samples were triggered for molecular vibrations through irradiation with infrared light and provide mostly information about the presence or absence of certain functional groups (Byler et al., 1991).

The data on Raman shift measured for adsorbents and fertilizers are given Figure 6a to d. The broad signal collected at 1125 and1108 cm^{-1} for zeolite and NZ, respectively. The Raman spectra in the fertilizer formulations such zeourea and nano-zeourea had a

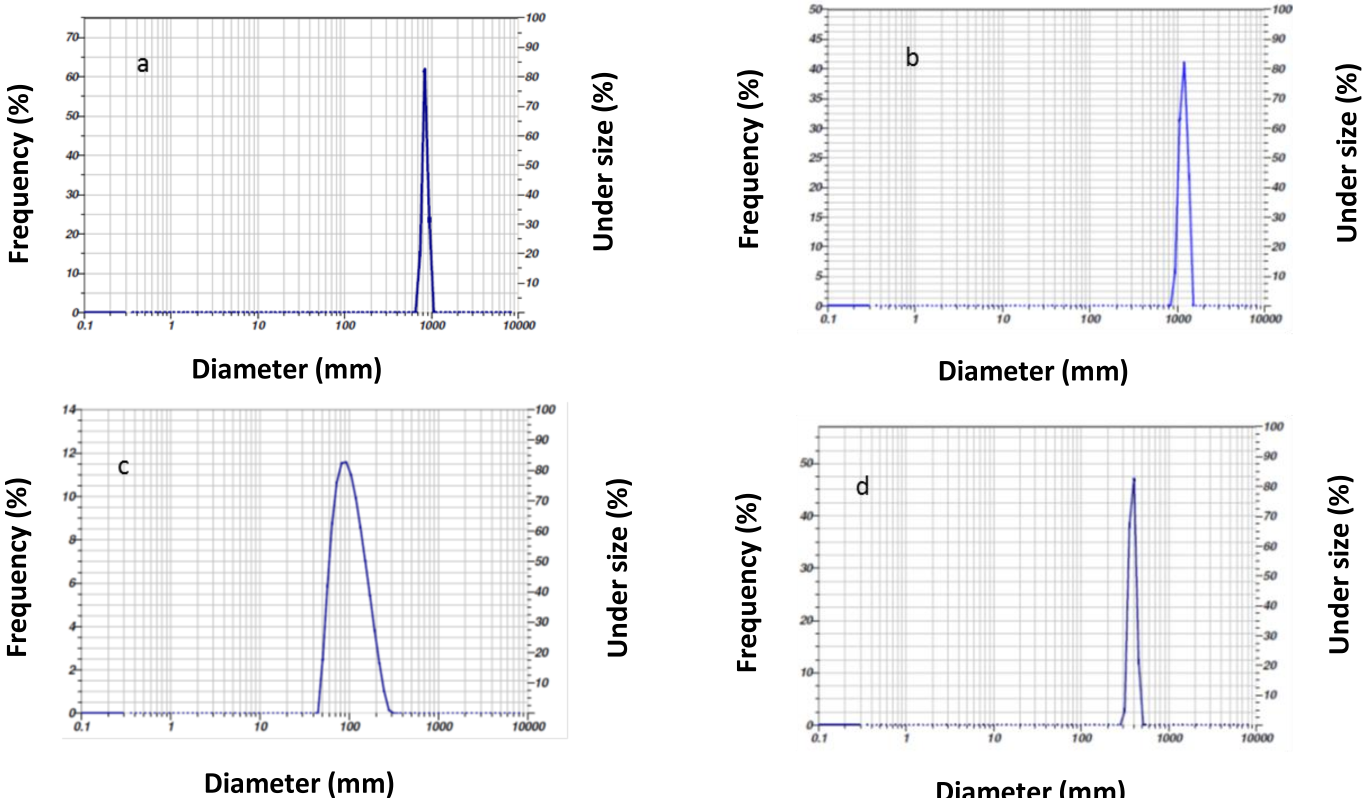


Figure 2. Particle size distributions (nm) of (a) Natural zeolite, (b) Zeourea, (1:1) (c) Nanoporous zeolite, (d) Nano-zeourea (1:1).

change in the magnitude of signal at 1114 and 1008 cm^{-1} indicating N on adsorbents (Frost, 1997; Peter et al., 2011). The intensity of the Raman signal decreases as particle size increases.

The surface morphology of NZ and nano-zeourea (1:1) was examined by SEM (Figure 7a to b). The N loading had changed the shapes and geometry of NZ from the sharp edges to the rounded besides aggregation of NZ. The EDS elemental analysis has estimated the silica and aluminium element ratios for NZ and nano-zeourea as 9.25/10.31 and 2.29/2.39, respectively (Figure 7a to b). Further, EDS quantified N content NZ and nano-zeo urea as 1.14 and 31.2%, respectively. The data clearly showed that, N has been successfully loaded into the adsorptive sites of NZ. The results are in conformity with the earlier observations (Sharmila, 2010; Ramesh et al., 2010; Komarneni, 2009) which have suggested size reduction of zeolite facilitates adsorption of NH_4 ions that is derived from the hydrolysis of urea.

Percolation reactor study

The release of NH_4^+-N and NO_3^- - N from adsorbents and fabricated fertilizers are presented in Figures 8 and 9). The data illustrated that, the NH_4^+-N release from urea, zeolite + urea (1:1), NZ: urea (1:1), zeourea, and nano-zeourea were 65, 45, 37, 21, and 18%, respectively, in the fertilizer formulations detected on the first day of the experiment (data not shown). Similar observations were reported earlier (Subramanian and Tarafdar, 2011; Ramesh et al., 2010). The first day of leachate solutions had 2716, 3486, 3346, 2758, and 2587 mg L^{-1} of NH_4^+-N and 490, 378, 280, 98, 126 mg l^{-1} of NO_3^- - N in urea, zeolite + urea (1:1), NZ: urea (1:1), zeo-urea and nano-zeourea, respectively.

The release of N from urea (irrespective of NH_4^+-N and NO_3^- - N) ceased to exist within 4 days of the experiment. The same set of treatments showed N release for 4, 13, 20, 34, and 48 days, respectively. This data strongly suggested that, NZ is a potential adsorbent to regulate the release of N. The percolation reactor study clearly demonstrated that, size reduction of the adsorbent assists in extensive surface area for N adsorption or desorption. Our data corroborated with the results of other published reports (Gholizadeh, 2008; Gioacchini et al., 2006; Zhang et al., 2006; Komarneni, 2009).

Conclusion

We made an attempt to improve the N use efficiency using NZ as an adsorbent. The N use efficiency of conventional urea hardly exceeds 30 to 35% and NZ has

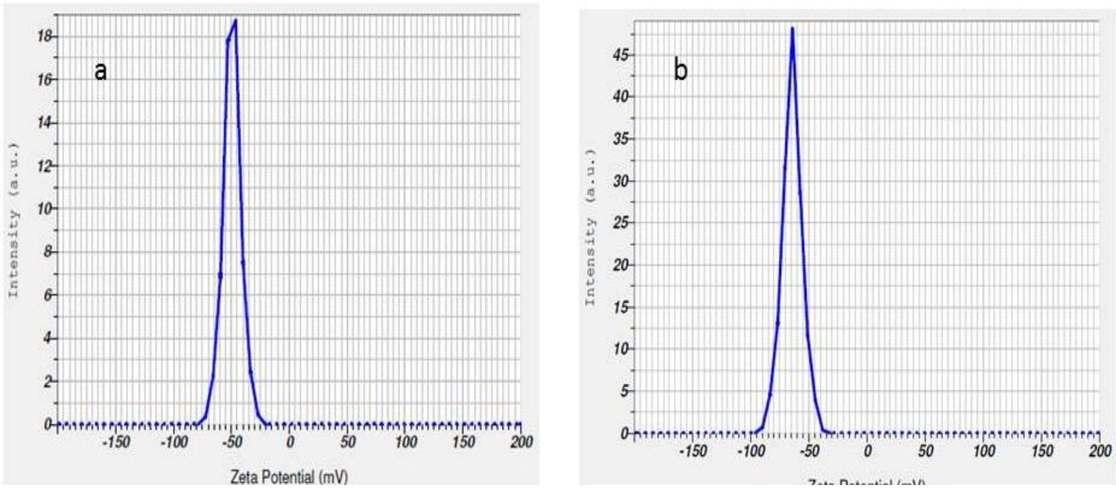


Figure 3. Zeta Potentials (mV) of (a) Zeourea (1:1), (b) Nano-zeourea (1:1).

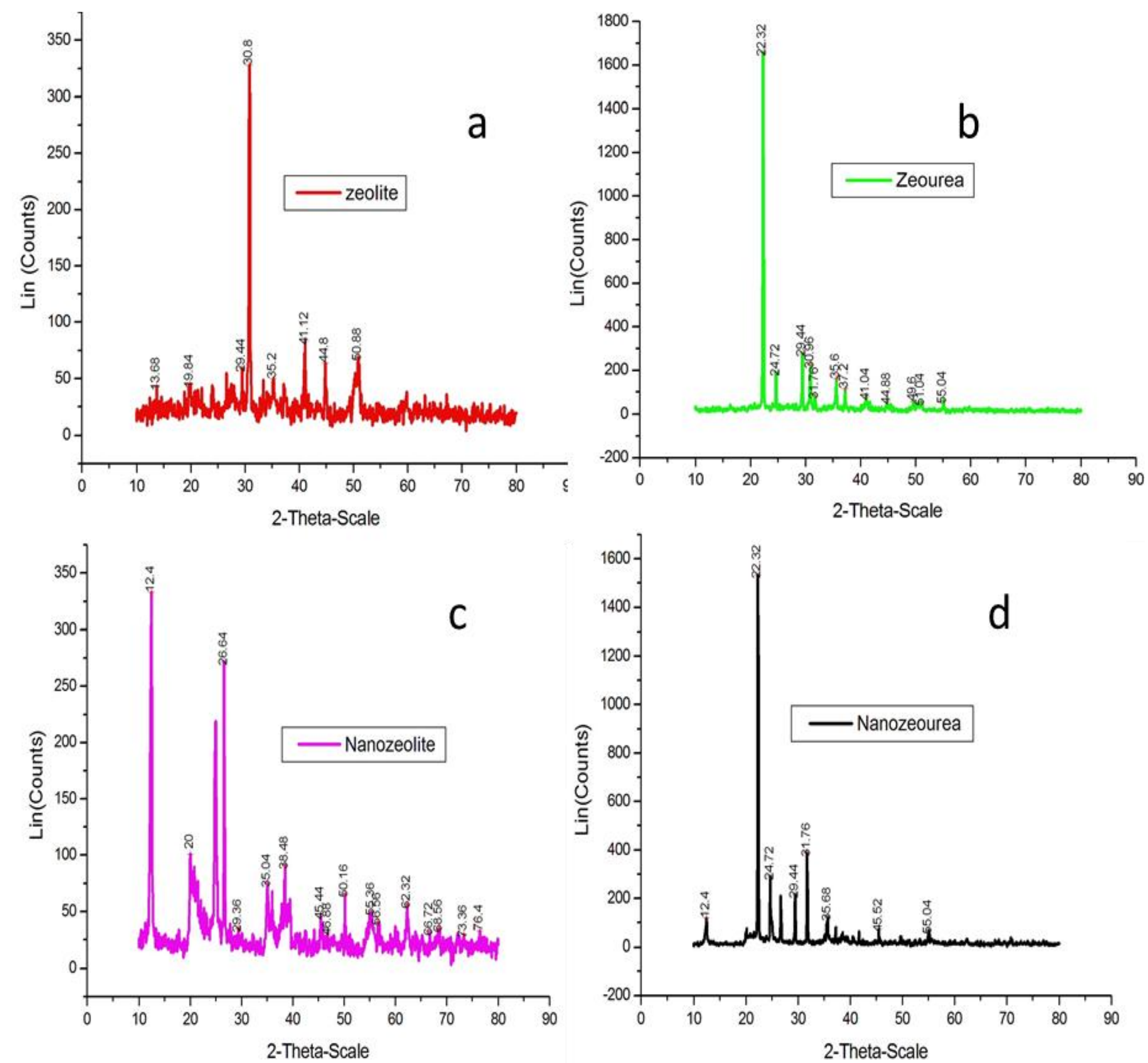


Figure 4. Powder X-ray diffraction patterns (Aº) of (a) natural zeolite, (b) zeourea (1:1), (c) nanoporous zeolite, (d) nano-zeourea (1:1).

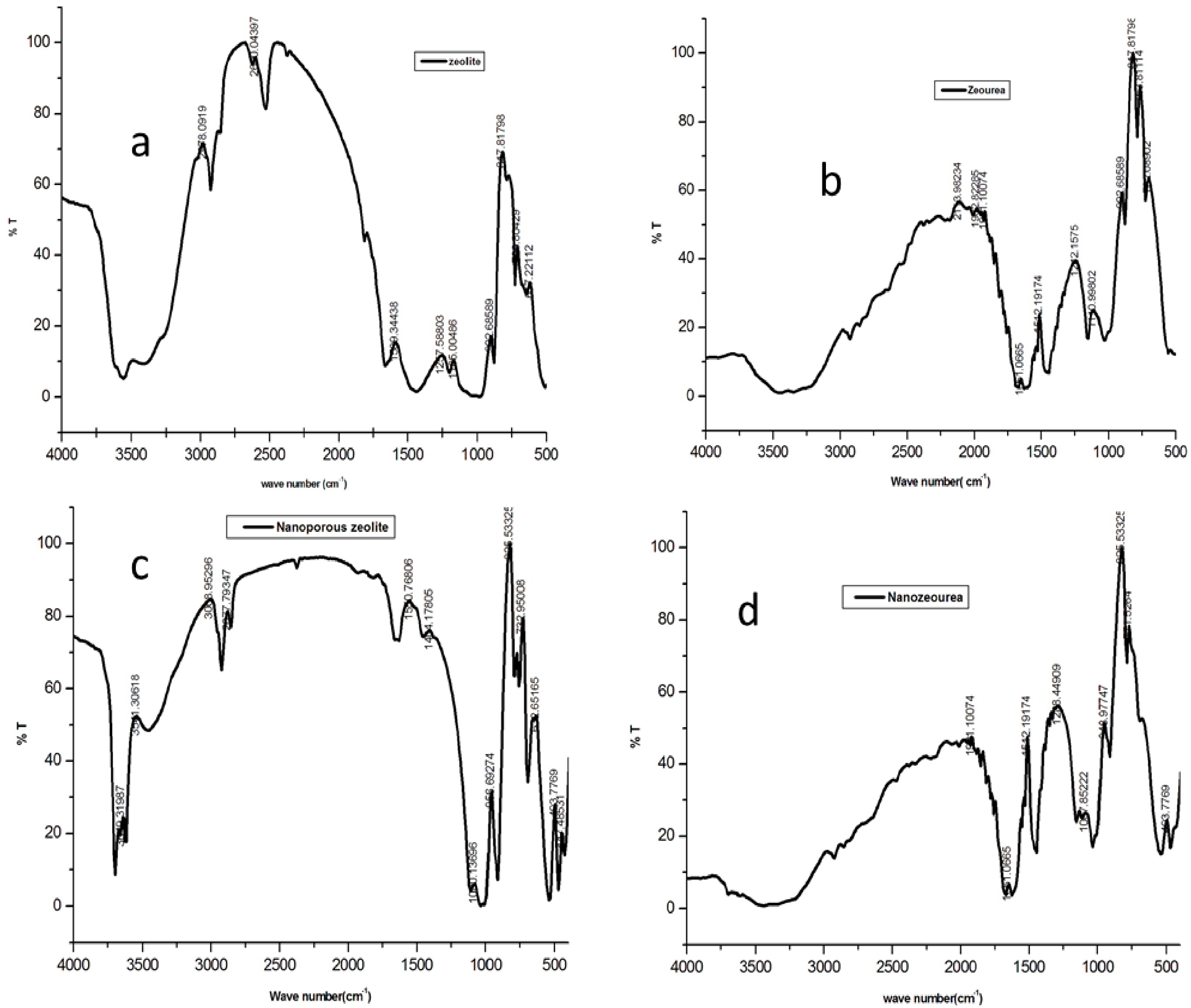


Figure 5. FT-IR spectra (cm^{-1}) of (a) natural zeolite, (b) zeourea (1:1), (c) nanoporous zeolite,, (d) Nano-zeourea (1:1).

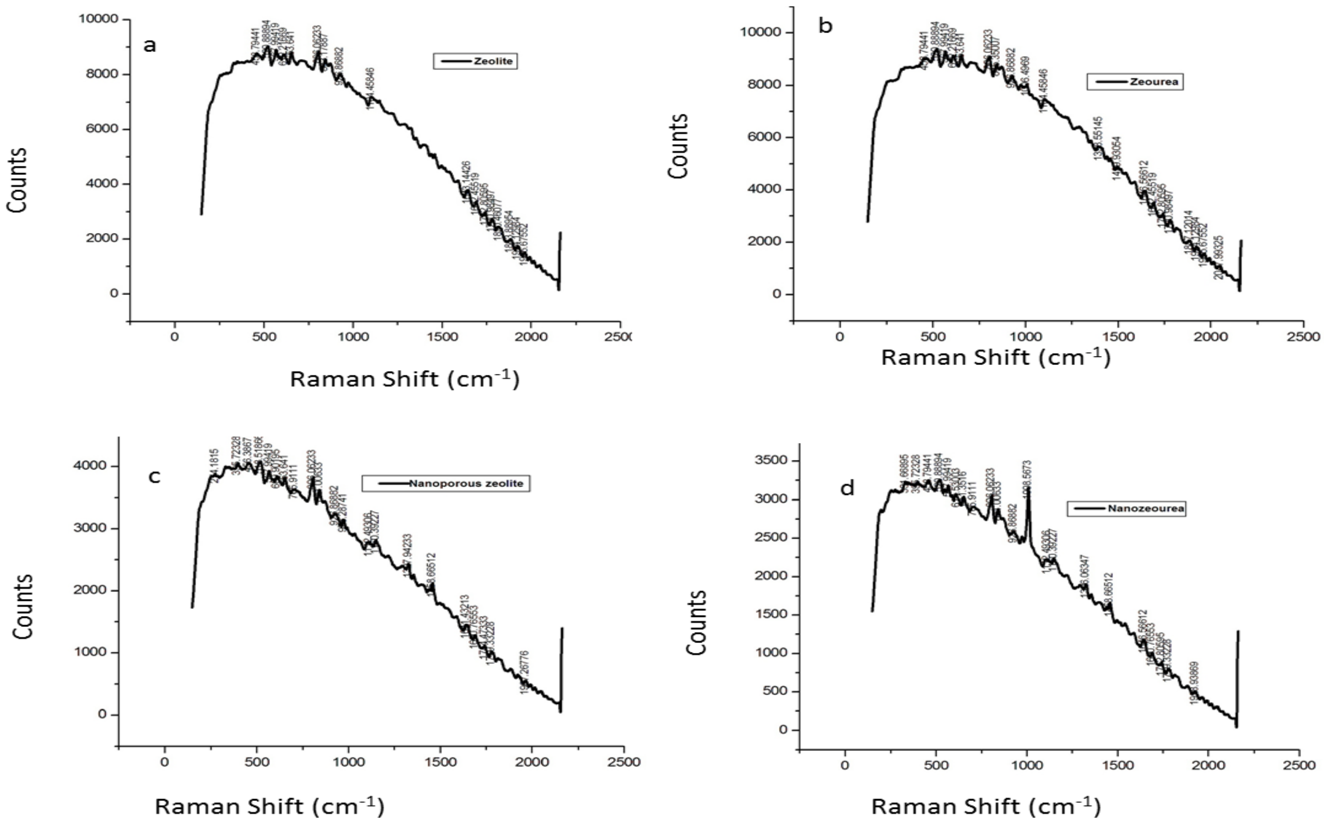
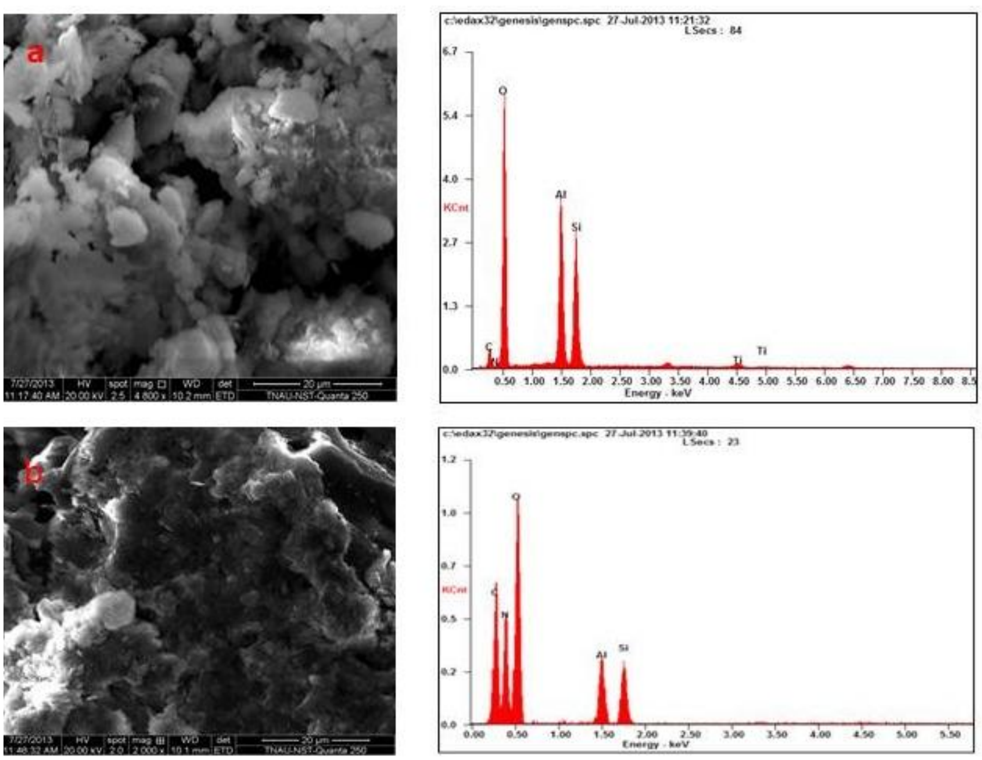


Figure 6. Raman Shift (cm^{-1}) of (a) natural zeolite, (b) neourea (1:1), (c) nanoporous zeolite, (d) Nano-zeourea (1:1).



Element	Wt %	At %
C K	11.15	16.42
N K	00.90	01.14
O K	56.52	62.50
AlK	15.73	10.31
SiK	14.68	09.25
TiK	01.01	00.37

Element	Wt %	At %
C K	19.93	24.78
N K	29.31	31.24
O K	42.12	39.30
AlK	04.33	02.39
SiK	04.30	02.29

Figure 7. SEM micrograms with EDS of (a) nanoporous zeolite, (b) nano-zeourea (1:1).

enormous potential to regulate the release of N thereby fertilizer use efficiency can be improved. NZ fortified urea facilitates adsorption of N in channels and porespaces. The zeourea and and nano-zeourea contained 18.5 and 28% of N and capable of releasing N up to 34 and 48 days, respectively, while the N release from conventional urea is just 4 days. The data strongly suggested that, zeolite with nano-dimension can help to improve N use efficiency besides sustained release of N that may considerably economize the N use in crops with an added advantage of prevention of groundwater contamination.

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Full Length Research Paper

Soil quality indicators under continuous cropping systems in the arid ecosystem of India

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Effect of cropping systems (CS) on the soil quality (SQ) and its determinants was assessed for the clay loam soil of Hisar, India. Collected surface soil samples were analyzed for four physical indicators viz. bulk density (BD), saturated hydraulic conductivity (SHC), porosity and mean weight diameter (MWD) seven chemical indicators viz. pH, electrical conductivity (EC), organic carbon (OC), nitrate nitrogen (NO_3-N), ammoniacal nitrogen (NH_4-N), available phosphorous (AV-P) and available potassium (AV-K) and two biological indicators viz. dehydrogenase activity (DA) and microbial biomass carbon (MBC). Correlation analysis of the 13 soil attributes representing soil physical, chemical, and biological parameters resulted in a significant correlation in twelve ($P < 0.01$) and nine ($P < 0.05$) attribute pairs out of the 47 soil attribute pairs. Each SQ indicator was compared with its value under different CS using Duncan Multiple Range Test (DMRT). The results indicated that, the soil properties such as BD, MWD, Av-P, Av-K, and DA were greatly influenced by the components of each CS. The adverse impact of CS on the SQ indicators resulted in deterioration of SQ. Evaluation of SQ using soil quality index (SQI) under CS showed that, SQ was better in T_2 (Cotton-wheat-fallow) and T_5 (Greengram-mustard+kasni) compared to other. The CS that exhibited negative impacts on SQ should be discouraged for long-term cultivation to maintain good soil health for sustainable agricultural production. Value of SQI was positively and significantly correlated ($R^2 = 0.50$, $P < 0.01$) with wheat equivalent yield for all the CS. This implies that, the index may have practical utility for quantifying the SQ.

Key words: Cropping system, soil quality, soil quality index, soil physical indicator, soil chemical indicator, and soil biological indicator.

INTRODUCTION

Agricultural sustainability has become a major concern in developing countries, including India. Population burst (> 1 billion), over-exploitation of natural resources, and excessive use of chemicals such as fertilizer, pesticide etc over many decades have resulted in steadily declining in agricultural productivity (Ladha et al., 2003; Masto et al., 2007). Issues of agricultural sustainability are related to soil quality, (SQ) assessment and the direction of change of SQ with time is a primary indicator of whether agriculture is sustainable (Karlen et al., 1997). It is therefore imperative to identify the soil characteristics responsible for changes in SQ, which may eventually be considered as determinants of SQ for assessing agricultural sustainability (Masto et al., 2007). SQ indicators are a

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composite set of measurable physical, chemical, and biological attributes which relate to functional soil processes and can be used to evaluate SQ status, as affected by management (Allen et al., 2011).

The concept of SQ emerged in the literature in the early 1990s (Wienhold et al., 2004) and defined as the capacity of a reference soil to function, within natural or managed ecosystem boundaries, to sustain plant and animal productivity, maintain or enhance water and air quality, and support human health and habitation (Karlen et al., 1997). SQ can be used interchangeably with soil health (Karlen et al., 2001) although it is important to distinguish that, SQ is related to soil function (Karlen et al., 2003; Letey et al., 2003), whereas soil health presents the soil as a finite non-renewable and dynamic living resource (Doran and Zeiss, 2000; Kinyangi, 2007).

SQ can be expressed by a unique set of indicators that include the physical, chemical and biological properties of soil. The performance of various soil functions are dictated by these indicators and the reverse is equally true. The soil functions can alter the SQ indicators thereby reducing the capacity of the soil to function. An important soil function is the crop production. Different management practices are followed under different cropping systems (CS) to optimize the biomass/agronomic production per unit area, per unit time and per unit input (Lal, 2003) and the soil attributes that are most sensitive to these managements are most desirable SQ indicators. The effect of CS on SQ can be assessed by measuring a range of physical, chemical, and biological soil properties. Cropping system treatments have significant effects on all soil properties measured especially in the surface soil layer (Jokela et al., 2011).

A better understanding of the impact of continuous cropping on soil physical, chemical, and biological properties is needed to optimize the soil conditions necessary to enhance the cropping system sustainability (Aparicio and Costa, 2007). Wienhold et al. (2006) have provided excellent data for assessing how management practices under CS collectively affect agronomic and environmental soil functions through changes in its indicators. The effects of various CS on SQ is mainly due to accumulation of soil organic matter, which can be affected by the quantity and type of C input from crop biomass and manure and by management such as tillage that affect the decomposition rate and stratification of soil organic matter (Weil and Magdoff, 2004; Jokela et al., 2011). Soil organic matter accumulation can improve SQ by decreasing bulk density (BD), surface sealing and crust formation (Mohanty et al., 2007), and by increasing aggregate stability (Somasundaram et al., 2013), cation exchange capacity, nutrient cycling, and biological activity (Karlen and Andrews, 2004). Dependence on fertilizers and other input can be reduced by enhancing biological nitrogen fixation and efficient utilization of water and nutrients through adopting appropriate CS (Lal, 2003).

Although advances in management have been adopted to enhance the cropping system performance through improvements in soil condition, research is needed to better understand the interactions of management, crop sequence, and cropping intensity on the broad spectrum of physical, chemical, and biological soil properties (Liebig et al., 2004).

The arid zone of India is characterized by low mean annual rainfall coupled with high coefficient of variation, large amplitude of fluctuations of diurnal and annual temperature, strong wind regimes and high potential evaporation. There are about 8.7% of such lands distributed in the Rajasthan, Gujarat, Punjab and Haryana (Anonymous, 2000). The region’s unpredictable climate has created challenge before agronomists and soil scientists to evolve suitable cropping system, which could be environmentally and economically sustainable. The paper summarizes;

(i) The relationship among soil physical, chemical and biological SQ indicators,
(ii) The effect of cropping system on soil properties, with particular focus on properties considered as SQ indicators,
(iii) Quantifying SQ under continuous cropping in arid ecosystem of India.

MATERIALS AND METHODS

Experimental site

The study area selected to achieve above-mentioned objective was Hisar center of Project Directorate for Farming Systems Research (PDFSR), Modipuram, Meerut, India. Hisar (29°5’N and 75°45’E) is located in the western agro climatic zone of Haryana. The climate of the center is tropical, arid, and hot, which is mainly dry with very hot summer and cold winter except during the monsoon season when moist air penetrates. The hot weather season starts from mid-March to last week of June with mean maximum temperature of about 41.6°C, followed by the south- west monsoon, which lasts up to September. The transition period from September to October forms the post-monsoon season. The winter season with mean minimum temperature of 5.5°C, starts in late November and remain up to the first week of March. The normal annual rainfall of the district is 459 mm (SD±178 mm), which is unevenly distributed over 23 rainy days. The southwest monsoon sets in from last week of June and withdraws in the end of September, contributing to about 81% of annual rainfall. July and August are the wettest months. Remaining 19% rainfall is received during the non-monsoon period in the wake of western disturbances and thunderstorms.

Experimental details and laboratory evaluation

The soil texture of the experimental site is clay loam containing 46% sand, 19% silt, and 35% clay and belongs to major soil group of alluvial soil. Seven CS, which were followed for more than ten years continuously on the same plot, were selected from the experiments conducted at the PDFSR center for this study (Table 1). Each CS was cultivated with standard management practice as recommended in arid eco-system and each cropping system was considered as one treatment. Soil samples from surface (0 to 15

Table 1. Seven cropping systems in Hisar under arid agro ecosystem.

Treatment	Kharif	Rabi	Summer
T_1	Pearl millet	Wheat	Fallow
T_2	Cotton	Wheat	Fallow
T_3	Pearl millet	Barley	Moong bean
T_4	Cluster bean	Broccoli	Onion
T_5	Moong bean	Mustard + Kasni	Fallow
T_6	Pearl millet	Wheat (Desi)	Cow pea
T_7	Pearl millet + moong	Wheat + Mustard	Fallow

Wheat (*Triticum aestivum*), Mustard (*Brassica juncea*), Cotton (*Gossypium spp.*), Cluster bean (*Cyamopsis tetragonoloba*), Broccoli (*Brassica oleracea*), Onion (*Allium cepa*), Kasni (*Cichorium intybus*), Cowpea (*Vigna unguiculata*), Pearl millet (*Pennisetum americanum*), Barley (*Hordeum vulgare*).

Table 2. Soil functions and appropriate soil quality indicator.

Soil function	Soil quality Indicators
Water and solute flow	Hydraulic conductivity, aggregate stability, organic carbon, bulk density and total porosity
Physical stability and support	Soil structure, soil texture, bulk density and aggregate stability
Nutrient cycling	Organic carbon, microbial biomass, enzyme activity, mineralizable nitrogen, pH and EC
Biodiversity, production	Organic carbon and nitrogen, ph, EC
Filtering and buffering	Texture, microbial biomass and organic carbon

cm) layer were collected from each treatment (cropping system) during year 2008 at the end of Rabi season (October to March) with three replications of each treatment. Each soil sample was analyzed for physical, chemical, and biological indicators of SQ.

These indicators were selected based on the performance of considered soil functions (Table 2). When SQ is assessed for its capability to produce agricultural yield, the indicators selected to represent the soil were BD, porosity, mean weight diameter (MWD), and saturated hydraulic conductivity (SHC) as physical indicators; soil pH, organic carbon (OC), electrical conductivity (EC), ammonical nitrogen (NH_4-N), nitrate nitrogen (NO_3-N), available phosphorous (AV-P) and available potassium (AV-K) as chemical indicators; microbial biomass carbon (MBC), and dehydrogenase activity (DA) as biological indicators. BD was determined by the core method (Blake and Hartge, 1986). Total porosity was calculated from the bulk and particle density. SHC was determined by constant head method (Klute and Dirkson, 1986). MWD was measured by wet sieving method (Yoder and McGuinness, 1956). NO_3-N and NH_4-N were determined by steam distillation method (Subbiah and Asija, 1956) using Kjeldhal apparatus. Soil pH and EC were measured in 1:2.5 soil-water suspensions. SOC was determined by wet digestion method (Walkley and Black, 1934). AV-P was determined using Olsen extractant (Olsen et al., 1954) and AV-K was determined in the neutral normal ammonium acetate extract of soil with the help of flame photometer (Jackson, 1967). MBC was measured by fumigation extraction method (Jenkinson and Ladd, 1979) and DH was determined using Casida method (Casida et al., 1964).

Soil quality index (SQI)

For developing a soil quality index (SQI), first the raw data of SQ indicators were transformed into normalized numerical scores ranging from 0 to 1 because different indicators are expressed by different numerical scales. The transformation of an indicator value to a score was achieved with the help of a scoring function. Three types of standardized nonlinear scoring functions were constructed namely:

(1) More is better (upper asymptotic sigmoid curve)
(2) Less is better (lower asymptotic sigmoid curve)
(3) Optimum curve (Gaussian function) (Karlen and Stott, 1994; Andrews et al., 2002). These curves were constructed using Curve Expert *v.*1.3. The shapes of the curves generated for various indicators were determined by their critical values. The weights of each parameter were assigned based on Principal Component Analysis (PCA). Each PC explained a certain amount of the variation in the total data set. This percentage, standardized to unity, provided the weight for variables chosen under a given PC (Andrews et al., 2002). After determining the weight of each determinant of SQ, SQI was calculated as Equation (1):

Table 3. Correlation matrix of soil quality indicators (n = 21).

Parameter	pH	EC	BD	Por	OC	SHC	MBC	DH	NO_3-N	NH_4-N	MWD	AV-P	AV-K
pH	1.00												
EC (dS cm^{-1})	-0.08	1.00											
BD (Mg m^{-3})	0.53**	-0.12	1.00										
Por (%)	-0.51**	0.12	-1.00**	1.00									
OC (%)	-0.13	-0.28*	-0.26*	0.27*	1.00								
SHC (cm h^{-1})	-0.29*	0.12	-0.48**	0.48**	0.29*	1.00							
MBC (µg g^{-1})	0.12	0.21	0.19	-0.12	0.01	0.14	1.00						
DH (µTPF g-1/24 hr)	-0.17	0.08	-0.36**	0.37**	0.23	.31*	-0.10	1.00					
NO_3-N (mg kg^{-1})	-0.01	-0.06	-0.08	0.08	0.04	0.23	-0.18	0.18	1.00				
NH_4-N (mg kg-1)	-0.09	0.12	-.28*	0.28*	-0.02	0.09	-0.30*	0.13	0.58**	1.00			
MWD (mm)	0.15	0.06	-0.19	0.18	0.01	-0.14	-0.03	0.19	-0.04	0.01	1.00		
AV-P (Kg ha^{-1})	-0.47**	0.04	-0.25	0.24	0.10	0.00	-0.22	0.11	-0.18	-0.11	-0.35*	1.00	
AV-K (Kg ha^{-1})	-0.46**	0.02	-0.10	0.10	-0.01	-0.13	0.11	-0.07	-0.11	-0.04	-0.28*	0.57**	1.00

**Correlation is significant at the 0.01 level, * Correlation is significant at the 0.05 level.

$$SQI = \frac{1}{n}\sum_{i=1}^{n} W_i * S_i \quad (1)$$

Where, n = number of indicators included in the index, S_i = linear or non linear score of ith indicator, W_i= weight assigned to ith indicator.

RESULTS AND DISCUSSION

Relationship among soil physical, chemical, and biological attributes

Correlation analysis of the 13 soil attributes representing soil physical, chemical, and biological parameters resulted in a significant correlation in 12 (P < 0.01) and 9 (P < 0.05) of the 47 soil attribute pairs (Table 3). Among the highly correlated parameter, we found a negative but significant linear relationship between BD and porosity at the surface layer. It is common to find negative relationship between BD and porosity, because porosity is directly related to inverse BD. Cropping system *vis a vis* management practices that incorporates more residue to soil, increases the porosity, also able to increase water holding capacity and sorptivity of the soil (Shaver, 2010).

In this study, BD and porosity is also showing high correlation with pH. Shaffer (1988) also observed pH is highly correlated with BD and porosity at the surface layer, but did not explain any reason. Sakin et al. (2011) further investigated the relationship between BD and pH and concluded that, there is no direct link existing between these two, but BD may be affected by pH because of its link with total exchangeable capacity, exchangeable Al hydroxyl, clay (content and nature) and iron-oxide.

The high OC is important for sustainability since it influences the determinants of SQ. Soil OC showed a significant correlation with all the physical properties *viz.* BD (r = -0.26), porosity (r = 0.27), HC (r = 0.29), and MWD (r = 0.71) consider in this study. Table 3 emphasized the role of OC in infiltration, water retention and movement in soil. Similar result has been observed by Sakin (2012) for BD and porosity, Aparicio and Costa (2007) for HC and Somasundaram et al. (2013); Mohanty et al., (2013) for MWD. In present investigation, soil pH is negatively and significantly correlated with Av-P (-0.47) and Av-K (-0.46). It indicated that, at higher pH, these nutrients are less available to crop. Wright et al. (2012) have critically reviewed the availability of plant nutrient under varying pH and suggested that, nutrients in soils are strongly affected by soil pH due to reacting with soil colloids and other nutrients, so; in fact, availability of many nutrients has been determined as a function of soil pH.

The DA showed significant correlation with BD, porosity and SHC (Table 3.). It indicates that, the soil physical environment may affect microbial activity in soil under arid ecosystem. Araújo et al. (2009) suggested that, measurement of soil property such as BD and porosity provides a relative value of soil compaction and reflects significant changes in macro-porosity and soil aeration, and consequently affects the soil microbial activity.

Soil physical quality indicator

The impacts of various management practices and CS on four soil physical indicators under the seven CS are exhibited in Table 4. Lowest and highest values of BD were observed under T_2 (Cotton - Wheat - Fallow) and T_1 (Pearl Millet - Wheat- Fallow), respectively. It is a well-known fact that, if BD increases, porosity goes down. Hence, maximum porosity was observed under T_2 and minimum under T_1 CS. For different soil textures, there are different ranges of optimum BD. In this study, the texture of soil was determined as clay loam, for which the ideal BD should be less than 1.40 Mg m^{-3} (USDA-NRCS, 2013). The comparison of BD after the rabi crops in the seven CS showed that, most of them leave soil with BD higher than the critical value (1.40 Mg m^{-3}) for clay loam soil. Only cotton- wheat-fallow (T_2) system maintained the most desirable BD (1.41 Mg m^{-3}). The pearl millet - wheat - fallow (T_1) system affected BD adversely to the maximum extent (1.61 Mg m^{-3}), which was significantly higher than T_2 system. To test the significance among CS, DMRT was performed and result showed that, BD under T_3, T_5, T_6, and T_7 were comparable, and it is higher than the critical limit in there CS. Generally, the values of BD higher than the critical limit may be due to the arid nature of the climate and clay loam soil texture. The hot and dry weather influences the clay loam soil to compact more and develop high BD, as the weather does not leave any water in top 15 cm soil and soil particles become dense. Porosity followed exactly the reverse trends.

In the present study, T_3 (Pearl Millet - Barley - Moong bean) showed maximum SHC whereas T_7 (Pearl Millet + Moong – Wheat + Mustard - Fallow) showed minimum SHC. This indicator of SQ is highly dynamic in nature and strongly influenced by the pore size distribution in soil rather than total porosity. The pore size distributions as well as surface pores are affected by many factors of management and rooting pattern of crop, which in turn are influenced by the arid nature of the agro ecosystem. Although, soil texture has a direct impact on SHC, indirect ecosystem influence is also important.

Mean weight diameter is an index of measurement of soil aggregation, which is important for the resistance of land surface to erosion, and it influences the ability of soil to remain productive (Pinheiro et al., 2004). Treatment T_6 (Pearl Millet – Wheat (Desi) –Cow Pea showed highest MWD (2.81 mm), and this is quite obvious because this cropping system includes cow pea, which has dense rooting pattern that binds the soil and reduces erosion.

Under T_4 (Clusterbean - Broccoli - Onion) MWD was lowest, and it was attributed to the presence of two vegetable crops in this treatment. Vegetable crops normally do not incorporate organic matter to soil and also have a very shallow root system which affects adversely soil aggregation (Sorensen, 2005).

Soil chemical and biological quality indicators

The measured values of soil chemical and biological indicators under the seven CS are mentioned in Table 5 and 6. When pH and EC of soil under all CS were compared using DMRT, no significant difference between CS was observed. Changes in pH of soil are attributed to the parent material and climate under which soil formation takes place. It has been reported that there is very little changes in pH within landscape units of few hectares (Shukla et al., 2004; Cox et al., 2003), which also corroborate our results. The detrimental effects of soil salinity are quantified in terms of soil EC. It occurs may be due to inappropriate soil drainage and use of saline water for irrigation. In this study, soil samples were collected from research center, which were irrigated with good-quality non-saline water and the soil was well drained. Hence, we did not find any difference in EC between the treatments of various CS. The comparison of AV-P and AV-K under different treatments, showed that the treatment T_4 (Clusterbean - Broccoli - Onion) exhibited maximum values for these indicators.

This may be due to the two vegetable crops of this cropping system. The uptake of phosphorous and potassium is much less in vegetable crops than in cereal crops and most of these nutrient uptake in vegetable are used for production of fruits, tuber or bulbs of the plants (Sainju, 2006). This causes high build-up of phosphorous and potassium in the soil leading to high values of these indicators. The minerals nitrogen in the forms of NH_4-N and NO_3-N were not affected much by the CS under arid agro ecosystems. The reason could be that the differences in soil mineral nitrogen due to CS were dominated by the influences of high temperatures existing after *rabi* harvest. This overshadowed the CS influences and resulted in non-significant differences of NH_4- and NO_3-N among the treatments. OC and MBC under the CS were non significant as indicated by DMRT. DA determines the metabolic activity of microorganism in soils. It is different from MBC and OC in the sense that it only constitutes living part of organic matter. Lowest dehydrogenase activity was observed under T5 (Moongbean Mustard + Kasni - Fallow) (Table 6). It could be because this system includes a medicinal plant 'Kasni' that has anti-microbial affects and suppresses the activity of micro-organism (Nishimura et al., 2000).

Table 4. Multiple comparisons (Duncan's method) of mean values of soil physical indicator among cropping systems.

Treatment	Cropping systems	BD ($Mg\ m^{-3}$)	SHC ($cm\ h^{-1}$)	Porosity (%)	MWD (mm)
T_1	Pearl millet - wheat - fallow	1.61^{b}	1.33^{a}	40.33^{a}	1.47^{ab}
T_2	Cotton -wheat - fallow	1.41^{a}	2.01^{ab}	46.95^{b}	2.20^{bc}
T_3	Pearl millet - barley - moongbean	1.50^{ab}	3.30^{b}	43.35^{ab}	1.72^{abc}
T_4	Clusterbean - broccoli - onion	1.57^{b}	1.70^{a}	40.93^{a}	0.70^{a}
T_5	Moongbean - mustard + kasni - fallow	1.54^{ab}	2.45^{ab}	42.06^{ab}	1.22^{ab}
T_6	Pearl Millet - wheat (desi) - cowpea	1.52^{ab}	1.41^{a}	42.46^{ab}	2.81^{c}
T_7	Pearl Millet + moong - wheat + mustard - fallow	1.52^{ab}	1.06^{a}	42.47^{ab}	$2.39b^{c}$

Mean followed by same letter are not significantly (P < 0.05) different according to Duncan's Multiple Range Test (DMRT at P<0.05). Wheat (Triticum aestivum), Mustard (Brassica juncea), Cotton (Gossypium spp.), Cluster bean (Cyamopsis tetragonoloba), Broccoli (Brassica oleracea), Onion (Allium cepa), Kasni (Cichorium intybus), Cowpea (Vigna unguiculata), Pearl millet (Pennisetum americanum), Barley (Hordeum vulgare).

Table 5. Multiple comparisons (Duncan's method) of mean values of soil chemical indicator among cropping systems.

Treatment	Cropping systems	pH	EC ($dS\ cm^{-1}$)	OC (%)	NH_4-N ($mg\ kg^{-1}$)	NO_3-N ($mg\ kg^{-1}$)	AV-P ($Kg\ ha^{-1}$)	AV-K ($Kg\ ha^{-1}$)
T_1	Pearl millet - wheat - fallow	7.58^{a}	0.48^{a}	0.95^{a}	87.74^{b}	50.21^{a}	28.41^{a}	289.71^{a}
T_2	Cotton - wheat - fallow	7.51^{a}	0.48^{a}	1.00^{a}	80.57^{b}	44.71^{a}	45.53^{a}	351.31^{a}
T_3	Pearl millet -barley - moongbean	7.55^{a}	0.52^{a}	0.97^{a}	81.73^{b}	48.82^{a}	36.06^{a}	279.63^{a}
T_4	Clusterbean - Broccoli - Onion	7.31^{a}	0.49^{a}	0.95^{a}	63.35^{b}	32.34^{a}	135.49^{b}	686.19^{b}
T_5	Moongbean - mustard + kasni – fallow	7.51^{a}	0.61^{a}	0.76^{a}	80.13^{b}	33.77^{a}	25.86^{a}	349.07^{a}
T_6	Pearl millet - wheat (desi) - cowpea	7.45^{a}	0.51^{a}	1.08^{a}	29.43^{a}	24.78^{a}	74.30^{ab}	233.71^{a}
T_7	Pearl millet + moong - wheat + mustard- fallow	7.48^{a}	0.52^{a}	1.07^{a}	67.50^{b}	28.26^{a}	27.32^{a}	297.55^{a}

Mean followed by same letter are not significantly (P < 0.05) different according to Duncan's Multiple Range Test (DMRT at P < 0.05). Wheat (*Triticum aestivum*), Mustard (*Brassica juncea*), Cotton (*Gossypium* spp.), Cluster bean (*Cyamopsis tetragonoloba*), Broccoli (*Brassica oleracea*), Onion (Allium cepa), Kasni (*Cichorium intybus*), Cowpea (*Vigna unguiculata*), Pearl millet (*Pennisetum americanum*), Barley (*Hordeum vulgare*).

Soil quality (SQ) under different cropping system

SQ determinant under seven cropping system in arid ecosystem is included for PCA and based on eigen value (Eigen value >1) and cumulative variance explained by principal component (73.64%) first five PCs were selected for further analysis (Table 7). Porosity was not included for PCA because of its high correlation with BD (r = 1) BD (Table 3). From selected PCs, highly weighted variable (loading factor > 0.40) (Wander and Bollero, 1999) were selected. Out of the twelve initially selected variables, which were chosen based on soil function (Table 2), eleven variables were finally selected for SQ assessment. The minimum data set suggested by PCA is EC, BD, HC, OC, MWD, NO_3-N, NH_4-N, Av-P, Av-K, DH, and MBC.

The SQ was calculated with Equation (1) for seven predominant CS of arid agro-ecosystem and compared using the DMRT (Figure 1.). The higher value of index implied that SQ under that cropping system is better compared to other. In the present investigation, we have observed better SQ under T_2 and T_5 (cotton-wheat-fallow and green gram–mustard+kasni-fallow). This result indicates that, cotton-wheat cropping system on clay loam soil generally does not deteriorate the physical, chemical and biological SQ indicator.

These systems affect and retain the values of SQ indicators in the desired range for their best performance except in case of MWD, MBC and NO_3-N, where the values were outside the desirable range and ten out of thirteen soil indicators remained in the best performing range. Hulugalle et al. (2006) also reported minimum deterioration in soil properties under cotton-wheat-fallow system. Similarly in T_5 (green gram – mustard + kasni - fallow), all the value are either in the higher range or medium range of performance, resulting in good SQ. The poorest SQ observed in this study was found under T_6 (pearl millet - wheat (desi)-cowpea). This could be because; this system adversely affected the soil aggregation and MBC. Cowpea is generally used as erosion resistant crop and promotes the soil aggregation and its stability. In other CS, the SQ was moderately good having index value 70 or above. This implied that, these CS do not deteriorate the SQ much. Further observation indicates that, SQ under T_2 was 33% better than T_6. The CS of T_1, T_3, T_4, and T_7 are in low index

Table 6. Multiple comparisons (Duncan's method) of mean values of soil biological indicator among cropping systems.

Treatment	Cropping systems	DA (μTPF g^{-1}/24 h)	MBC ($\mu g\ g^{-1}$)
T_1	Pearl millet - wheat - fallow	122.87^{b}	82.86^{a}
T_2	Cotton -wheat - fallow	100.80^{ab}	132.86^{a}
T_3	Pearl millet - barley - moongbean	104.87^{ab}	95.71^{a}
T_4	Clusterbean - broccoli - onion	84.27^{ab}	125.71^{a}
T_5	Moongbean - mustard + kasni - fallow	68.20^{a}	151.43^{a}
T_6	Pearl millet - wheat (desi) - cowpea	92.67^{ab}	112.86^{a}
T_7	Pearl millet + moong - wheat + mustard - fallow	107.67^{ab}	121.43^{a}

Mean followed by same letter are not significantly ($P < 0.05$) different according to Duncan's Multiple Range Test (DMRT at $P < 0.05$). Wheat (*Triticum aestivum*), Mustard (*Brassica juncea*), Cotton (*Gossypium* spp.), Cluster bean (*Cyamopsis tetragonoloba*), Broccoli (*Brassica oleracea*), Onion (*Allium* cepa), Kasni (*Cichorium intybus*), Cowpea (*Vigna unguiculata*), Pearl millet (*Pennisetum americanum*), Barley (*Hordeum vulgare*).

Table 7. Component matrix of soil quality determinant for arid ecosystem.

Parameter	PC1	PC2	PC3	PC4	PC5
Eigen value	2.45	2.12	1.65	1.50	1.12
% of variance	20.38	17.65	13.78	12.53	9.30
Cumulative percentage of variance	20.38	38.03	51.81	64.35	73.64
pH	0.50	-0.23	0.01	-0.02	0.33
EC (dS cm^{-1})	-0.21	-0.71	0.47	0.14	-0.01
BD (Mg m^{-3})	-0.08	0.41	0.22	-0.68	-0.08
HC (cm h^{-1})	0.33	0.22	0.21	0.30	-0.64
OC (%)	0.15	0.76	-0.46	0.12	-0.16
MWD (mm)	0.26	-0.47	-0.72	0.14	0.06
NO_3-N (mg kg^{-1})	0.64	0.44	0.43	0.02	0.09
NH_4-N (mg kg^{-1})	0.37	-0.01	0.58	0.44	0.15
AV-P (Kg ha^{-1})	-0.66	0.33	-0.06	0.28	0.37
AV-K (Kg ha^{-1})	-0.69	0.43	0.21	0.27	0.29
DH (µTPF g-1/24h)	0.61	0.24	-0.19	0.41	0.39
MBC ($\mu g\ g^{-1}$)	-0.36	-0.06	-0.08	0.62	-0.41

Boldface factor loading are consider highly weighted.

value subgroup whereas, T_2 and T_6 cropping system constituted high index value sub group in surface layer according to DMRT.

Crop productivity is one of the reliable ways to evaluate the SQ (Mohanty et al., 2007). In the present investigation, high and significant correlation was observed between index values and wheat equivalent yield (Figure 2). A positive correlation ($R^2 = 50$) between index values and yield implies that, the index may have utility for quantifying the SQ under the mentioned CS.

Conclusion

The assessment of SQ indicators under different CS in clay loam soil and under arid ecosystem showed that, the physical condition of soil is influenced by the cropping system. Pearl millet - wheat - fallow (T_1) cropping system deteriorated the physical condition of soil as is expressed by very high BD under this system, also inclusion of vegetables in the cropping system were not desirable from soil structure point of view as they did not result in optimum soil aggregation. The various CS did not influence chemical environment significantly with the only exception where onion is included in cropping system. In general, the CS does not affect MBC significantly; however, inclusion of kasni with cereal and pulses resulted in very low DA due to its anti microbial effect in soil. The adverse impact of CS on SQ indicators results in deterioration in quality of soil in such CS and these CS

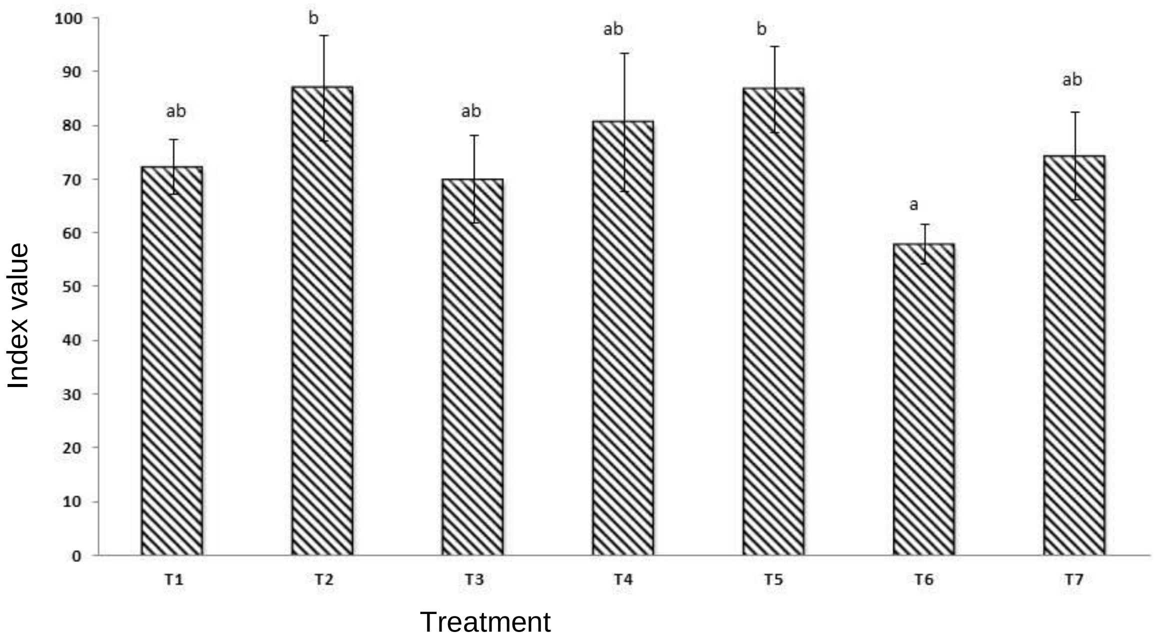

Figure 1. Soil quality under different cropping system. T_1; pearl millet - wheat – fallow, T_2; Cotton -wheat – fallow, T_3; Pearl millet - Barley - Moongbean, T_4; Clusterbean - Broccoli – Onion, T_5; Moongbean - Mustard + Kasni - Fallow, T_6; Pearl millet - Wheat (desi) – Cowpea, T_7; Pearl millet + Moong - Wheat + Mustard – Fallow. Same letter(a, b, c…) are not significantly different according to Duncan's Multiple range Test (DMRT at $P < 0.05$). Wheat (*Triticum aestivum*), Mustard (*Brassica juncea*), Cotton (*Gossypium* spp.), Cluster bean (*Cyamopsis tetragonoloba*), Broccoli (*Brassica oleracea*), Onion (*Allium cepa*), Kasni (*Cichorium intybus*), Cowpea (*Vigna unguiculata*), Pearl millet (*Pennisetum americanum*), Barley (*Hordeum vulgare*).

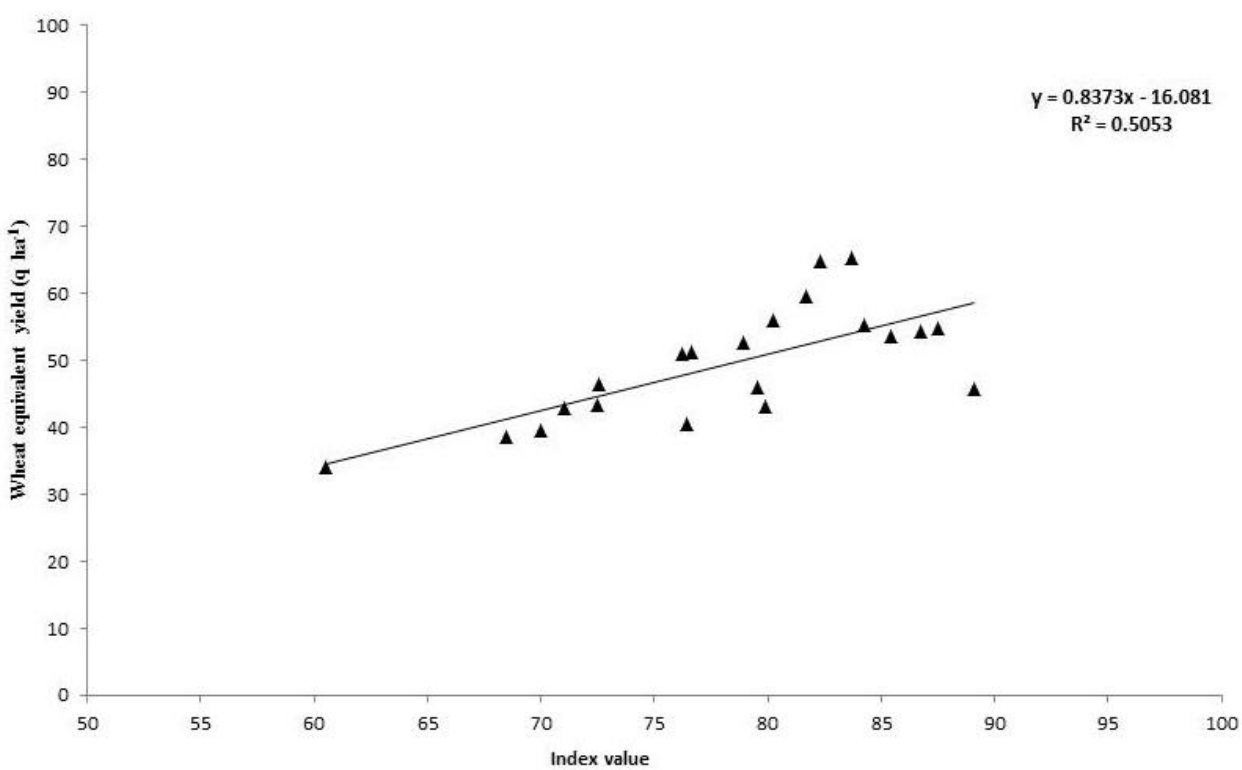

Figure 2. Correlation between SQI and wheat equivalent yield.

should be prevented for long-term cultivation.

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Drip fertigation could improve source-sink relationship of aerobic rice (*Oryza sativa* L.)

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The present study investigated variations among different water and fertilizer levels of aerobic rice. The data collected to assess the source-sink relationship of aerobic rice were leaf number, individual leaf size, soluble protein content and leaf area duration expressed as source strength and moreover sink strength expressed using spikelet number, thousand grain weight, grain filling duration and grain filling rate. The higher sink strength and optimum source strength was recorded in 125% pan evaporation (PE) with 100% recommended doses of fertilizers (RDF) treatment. Besides, higher sink-source ratio and lower source limitation was a reason for the balanced source and sink strength observed and also recorded higher grain yield. The treatments receiving 100% PE and 75% RDF level showed considerable reduction in the grain yield through source sink related characters.

Key words: Aerobic rice, drip fertigation, source strength, sink strength, grain filling rate.

INTRODUCTION

Rice is an important food crop for a large proportion of the world's population. It is staple food in the diet of the population of Asia. Rice provides 35 to 60% of the dietary calories consumed by nearly more than 3 billion people (Fageria et al., 2003). Globally, it is also the second most cultivated cereal after wheat. Unlike wheat, 95% of the world's rice is grown in less developed nations, primarily in Asia, Africa and Latin America. China and India are the largest rice producing and consuming countries in the world (Fageria, 2007). By the year 2025, it is estimated that it will be necessary to produce about 60% more rice than what is currently produced to meet the food needs of a growing world population. In addition, the land available for crop production is decreasing steadily due to urban growth and land degradation. Hence, increases in rice production will have to come from the same or an even less amount of land. This means appropriate rice production practices should be adopted to improve rice yield per unit area (Fageria, 2007).

Aerobic culture is an emerging technology designed to enhance water use efficiency in rice production (Tuong et al., 2005; Matsuo and Mochizuki, 2009), by growing the plants in non-puddled, non-flooded fertile soils (Atlin et al., 2006; Haryanto et al., 2008; Matsunami et al., 2009). In a previous study, we suggested that aerobic culture could save water without any yield penalty compared with flooded culture, but with some risks of poor performance (Kato et al., 2009). High crop yields are determined by ability of plants to produce high levels of photoassimilate and/or to partition large proportions of carbohydrate efficiently into harvested organs (Faville et al., 1999). Assimilate producing plant parts such as leaves are known as the source, and plant parts to which assimilate is translocated to grains are known as the sink (Fageria et al., 2007). In crop plants, physiological basis of dry matter production is dependent on source-sink concept, where source is a potential capacity for photosynthesis and sink is a potential capacity to utilize photosynthetic products. If sink is small and large, the yield cannot be high if source capacity is limited. A developing leaf is a

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sink, but when fully grown it becomes a potential source. Sink size has a potential capacity for maximum production of a crop (Venkateswarlu and Visperas, 1987).

Source is the first organ to respond to management practices. Therefore, source may suffer if stress affects its balance with sink (Venkateswarlu and Visperas, 1987). Source is more sensitive to cultural, nutritional and climatic factors. Nutritional and cultural practices often stimulate source thus making it more responsive. Since several parameters concerning the physical frame of the plants are almost exhaustively studied, it is likely that the manipulation of functional traits might enhance the yield plateau especially under low-yielding aerobic environment. Realizing this aspect, attempts are made to elucidate the 'source' (leaf) and 'sink' (panicle) inter-relationships to improve the functional efficiency of the rice plants intended for aerobic environment.

MATERIALS AND METHODS

Field experiment was conducted in Wetland, Tamil Nadu Agricultural University, Coimbatore, India during dry season (2007) (11°N, 77°E). The experimental plots were dry-ploughed and harrowed. Raised flat beds were formed and laid out with double channels around all the plots. Before sowing, the wet seeds were treated with the *Azophosmet* biofertilizer at the rate of 200 g 10 kg^{-1} of seeds and sprouted, biofertilizer treated seeds were dry-sown by hand dibbling at 3 cm depth in rows 20 cm apart and covered with soil, in the field for all the treatments except the conventional practice (T_1) at seeding rates of 30 kg ha^{-1}. A pre-emergence herbicide of pendimethalin at 1.25 kg a.i. ha^{-1} was applied 3 days after the first irrigation and later hand weeding was taken at 35 days after sowing for maintaining weed free environment.

Fertigation

The fertigation schedule indicating that the nutrient requirement at different pheonological stages and quantity of nutrients to be applied for 75, 100 and 125% recommended dose of NPK (150:50:50 kg ha^{-1}) respectively (Figure 1a to c). All the three fertilizers *viz*., nitrogen, phosphorus and potassium were supplied through fertigation in the form of water soluble fertilizers as per the drip fertigation treatments once in a week. In the case of conventional method (T_1), entire dose of P was applied basally before sowing. In the case of N, the recommended dose was given in four equal splits at basal, tillering, panicle initiation and first flowering; while, K was given in two equal splits at basal and panicle initiation stages. Recommended doses of $FeSO_4$ (50 kg ha^{-1}) and $ZnSO_4$ (25 kg ha^{-1}) were applied as the basal dressings before sowing in all the ten treatments.

Depth or volume of irrigation water was measured using the discharge of the delivery hose connected in the pump, time of irrigation, and surface area of the plot. Calibration of water discharge from the delivery hose was done by measuring the discharged water using graduated cylinder at a certain time. It was done in a series of trials at different sections or length of delivery hose. With the given depth of irrigation, size of plot and average discharge of the delivery hose, the time of irrigation for every plot was computed. Drip fertigation treatments comprised of three water and fertilizer levels.

The following treatments were employed in the present study: T_1: Surface irrigation given at 3 cm depth with IW/CPE ratio of 1.0 + 100% RDF (Soil application at 150:50:50 NPK kg ha^{-1}). T_2: Drip fertigation at 100% PE + 75% RDF. T_3: Drip fertigation at 100% PE + 100% RDF. T_4: Drip fertigation at 100% PE + 125% RDF. T_5: Drip fertigation at 125% PE + 75% RDF. T_6: Drip fertigation at 125% PE + 100% RDF T_7: Drip fertigation at 125% PE + 125% RDF. T_8: Drip fertigation at 150% PE + 75% RDF. T_9: Drip fertigation at 150% PE + 100% RDF. T_{10}: Drip fertigation at 150% PE + 125% RDF (PE: Pan Evaporation; RDF: Recommended Doses of Fertilizers). From these treatments the mean performance was calculated for water regimes are 100, 125 and 150% PE and for fertilizer regimes are 75, 100 and 125% RDF. These were replicated thrice with randomized complete block design.

Sampling and data collection

Source characteristics

Four hills from each replication and treatment were removed and the leaf was counted as a single unit. The number of leaves per hill was presented by calculating the mean of four hills. Leaf area duration (LAD) was determined by using the formula of Power et al. (1967) and the values expressed in days. The individual leaf size (ILS) was calculated by using the formula of ILS = Total leaf area (cm^2 $hill^{-1}$) / Total leaf number $hill^{-1}$ and expressed in cm^2 $leaf^{-1}$. Soluble protein was estimated from the rice leaves by the method of Lowry et al. (1951) and expressed as mg g^{-1} fresh weight.

Sink characteristics

For panicle growth modeling, at the time of flowering, about one hundred panicles in the each treatment in three replications were tagged (Jaiswal et al., 1982). The panicles were sampled periodically and their dry weights collected at the chosen time interval were plotted as a function of time from anthesis until the final harvest. Panicle data from the treatments were fitted with different panicle growth models as proposed by Thornley (1976). Models are exponential (negative), Gompertz, logistic, cubic, polynomial, quadratic and Richard's and a hybrid of Richard's-Quadratic model. Among them, the hybrid model of Richard's - Quadratic was found to be best fit.

The Richard's - Quadratic (hybrid) equation used by Mohandass et al. (1988) was $W_t = W_f\ [1 + e^{\theta(t)}]^{-1/n}$. Where, W_t and W_f were panicle dry weight at time 't' and at maturity respectively, and θ(t) is the quadratic polynomial in 't'. The value of 'n' in this model was found to be 0.1. From these models and functions (Figure 2 and Tables 1 and 2), observations were made of the dates on which 90% of the final panicle weights were attained and the relative duration of the grain filling duration (GFD) of each treatment was calculated as the length of the time interval from zero flowering (anthesis) to the predicted date of 90% of final grain yield (Jones et al., 1979). The dry matter accumulated by the panicle at 90% of the final panicle weight was divided by the GFD to arrive at the grain filling rate (GFR). Sink capacity was calculated as the product of spikelets/ m^2 and test weight (Yoshida, 1981). Sink-limitation was worked out as spikelet number x 1000 grain weight / Leaf Area at flowering (Rao and Murty, 1976). Approximate source-limitation (Sa) was calculated by taking into account the changes in dry weight of panicle (ΔY) and the biomass (ΔB) due to variation in treatments as: Sa = (ΔY) / (ΔB) (Gifford et al., 1973). Grain yield adjusted to 14% moisture content was obtained from the whole area of the plot.

Statistical analysis

The data collected were subjected to statistical analyses in the randomized block design using ANOVA (AGRES version 7.01)

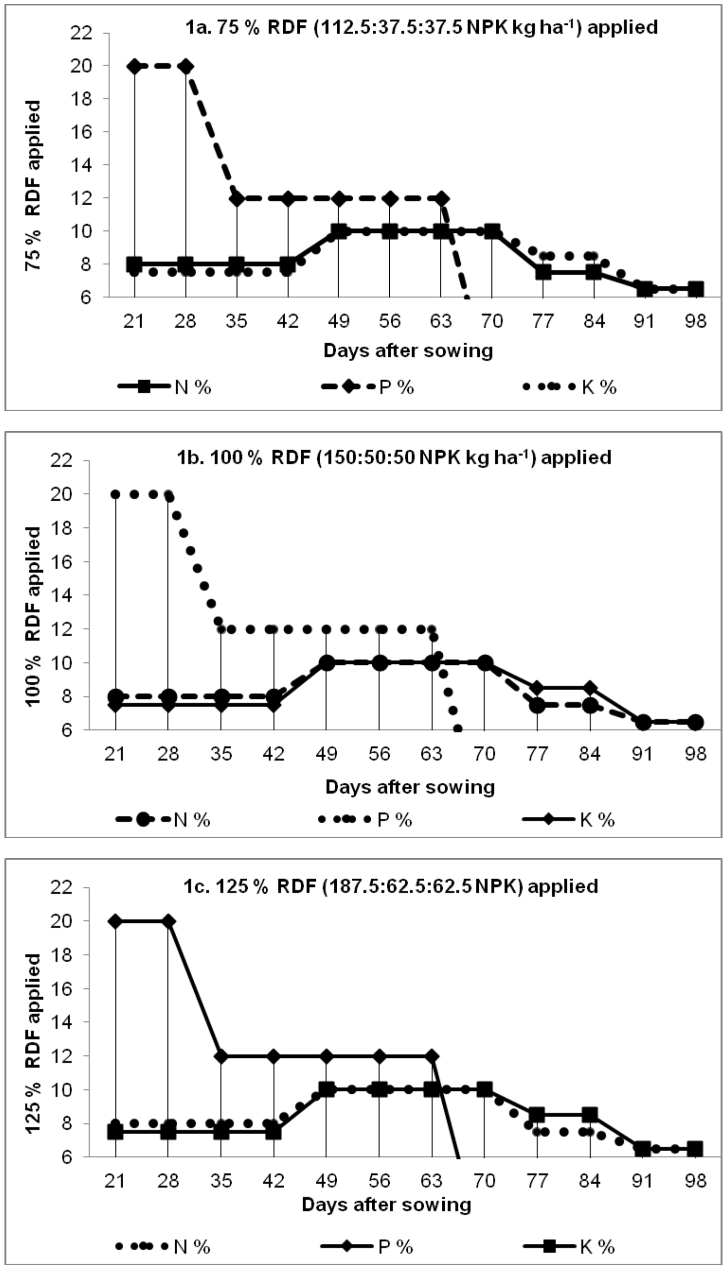


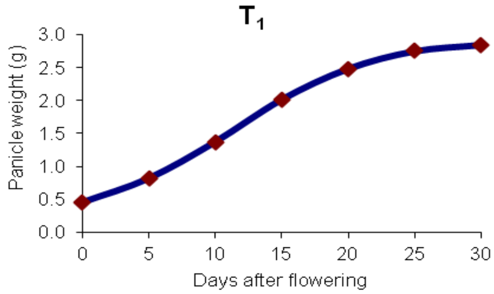
Figure 1. Details of fertilizers applied through fertigation.

following the method of Gomez and Gomez (1984).

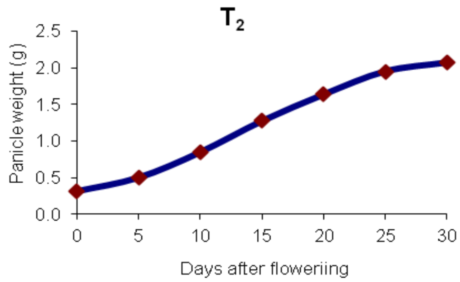
RESULTS AND DISCUSSION

Source characteristics

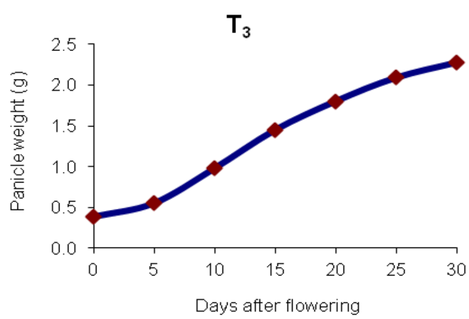
Leaves are the dominant primary source for producing assimilates in crop plants. Photosynthetic activities of plant parts other than leaf blades are very small for rice. The source strength is the major factor influencing the sink strength (Yoshida, 1981). Source strength has got two components, viz., source size and its activity. The source activity is further split into two sub-components that is, photosynthetic efficiency (in terms of soluble protein content, is an indirect measurement of photosynthetic capacity) and longevity of source (LAD). It is noticed that the source size (in terms of both leaf number and ILS at flowering stage) increased with increase in water availability (Table 3). Interestingly, the reduction in soluble protein content with lower water availability (100% PE) was found to be 12.7 and 19.5% in comparison with 125 and 150% PE level of drip irrigation respectively.



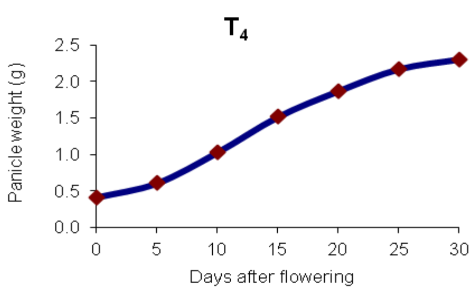
T_1: Conventional method



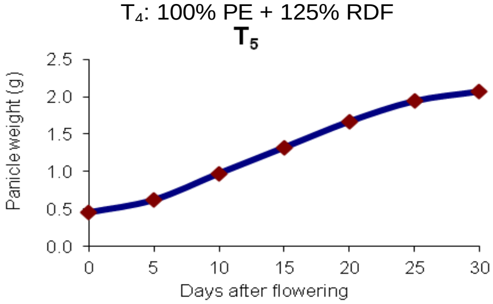
T_2: 100% PE + 75% RDF



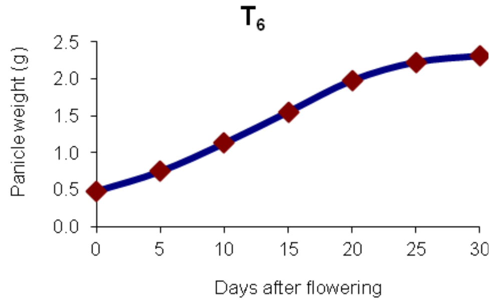
T_3: 100% PE + 100% RDF



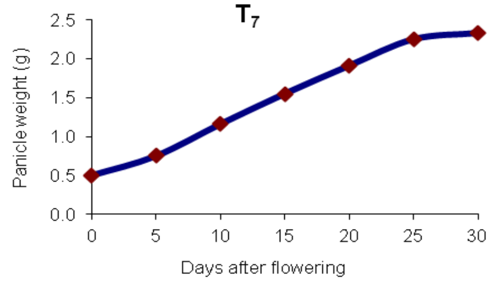
T_4: 100% PE + 125% RDF



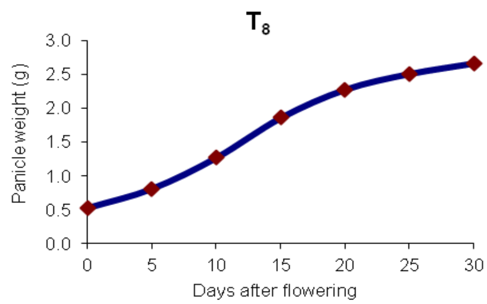
T_5: 125% PE + 75% RDF



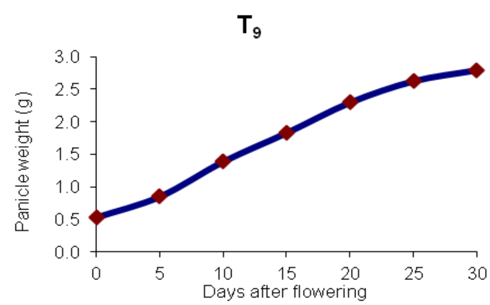
T_6: 125% PE + 100% RDF



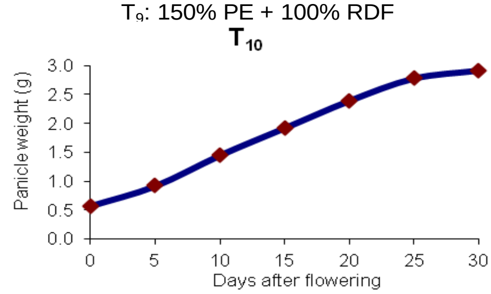
T_7: 125% PE + 125% RDF



T_8: 150% PE + 75% RDF



T_9: 150% PE + 100% RDF



T_{10}: 150% PE + 125% RDF

Figure 2. Richard's - Quadratic (Hybrid) model for panicle growth in drip fertigated aerobic rice.

Table 1. Richard's - quadratic (hybrid) function for panicle growth in drip fertigated aerobic rice.

Treatment	Richard's – Quadratic (Hybrid) function	R^2
T_1: Conventional method	$W = 2.85\ [1 + e^{-(1.711 + 0.021\ t + 0.0032\ t2}]^{-10}$	0.9801**
T_2: 100% PE + 75 % RDF	$W = 2.07\ [1 + e^{-(1.227 + 0.038\ t + 0.0032\ t2}]^{-10}$	0.9215**
T_3:100% PE + 100 % RDF	$W = 2.28\ [1 + e^{-(1.242 + 0.037\ t + 0.0028\ t2}]^{-10}$	0.9128**
T_4:100% PE + 125 % RDF	$W = 2.31\ [1 + e^{-(1.256 + 0.035\ t + 0.0024\ t2}]^{-10}$	0.9022**
T_5:125% PE + 75 % RDF	$W = 2.08\ [1 + e^{-(1.437 + 0.037\ t + 0.0032\ t2}]^{-10}$	0.9324**
T_6:125% PE + 100 % RDF	$W = 2.31\ [1 + e^{-(1.518 + 0.033\ t + 0.0035\ t2}]^{-10}$	0.9735**
T_7:125% PE + 125 % RDF	$W = 2.33\ [1 + e^{-(1.509 + 0.035\ t + 0.0033\ t2}]^{-10}$	0.9626**
T_8:150% PE + 75 % RDF	$W = 2.67\ [1 + e^{-(1.391 + 0.038\ t + 0.0033\ t2}]^{-10}$	0.9258**
T_9:150% PE + 100 % RDF	$W = 2.80\ [1 + e^{-(1.448 + 0.035\ t + 0.0035\ t2}]^{-10}$	0.9178**
T_{10}:150% PE + 125 % RDF	$W = 2.92\ [1 + e^{-(1.216 + 0.037\ t + 0.0035\ t2}]^{-10}$	0.9279**

Table 2. Grain filling duration (GFD) and its rate (GFR) as influenced by drip fertigation treatments in aerobic rice.

Treatment	GFD (Days)	GFR (mg panicle^{-1} day^{-1})
T_1: Conventional method	26.95	64.22
T_2: 100% PE + 75% RDF	24.15	44.01
T_3:100% PE + 100 % RDF	25.41	46.32
T_4:100% PE + 125% RDF	26.49	42.39
T_5:125% PE + 75 % RDF	26.12	61.55
T_6:125% PE + 100% RDF	26.48	72.98
T_7:125% PE + 125% RDF	27.15	67.69
T_8:150% PE + 75% RDF	26.59	60.35
T_9:150% PE + 100% RDF	27.15	65.21
T_{10}:150% PE + 125% RDF	27.66	62.34

Table 3. Components of source strength due to drip fertigation in aerobic rice.

Treatment	Source size		Source activity	
	Leaf number hill^{-1}	ILS (cm^2 leaf^{-1})	Soluble protein (mg g^{-1})	LAD (Days)
Irrigation regime				
100% PE	77.87	9.77	7.46	99.2
125% PE	97.23	12.17	8.55	127.7
150% PE	115.70	12.73	9.27	134.4
Fertilizer regime				
75% RDF	84.67	10.67	7.74	112.1
100% RDF	95.93	10.90	8.43	118.9
125% RDF	110.23	13.10	9.10	130.3
Conventional practice	110.30	10.50	10.15	152.4

Similar trend was evident with LAD also with greater magnitude of reduction in the case of lower water availability situation. These trends implied that under water stressed environment at 100% PE level, fair crop productivity could be achieved when optimum leaf area was maintained with greater and sustained photosynthetic efficiency. This association appeared valid only when proper efficient varieties and good agronomic management practices (such as the fertigation at optimum RDF level) were ensured for the stressed situations.

Table 4. Components of sink strength due to drip fertigation in aerobic rice.

Treatment	Sink capacity (g m^{-2})	Sink size(No. m^{-2})	Sink activity	
			GFD (days)	GFR (mg $panicle^{-1}d^{-1}$)
Irrigation regime				
100 % PE	638.87	28.07	25.4	44.24
125 % PE	789.34	32.35	26.6	67.41
150 % PE	744.44	30.51	27.1	62.63
Fertilizer regime				
75 % RDF	682.84	28.58	25.6	48.56
100 % RDF	740.81	30.79	26.4	64.22
125 % RDF	749.00	31.55	27.1	61.50
Conventional practice	739.45	30.12	27.2	57.47

Sink characteristics

Sink strength consists of two major components, *viz*., sink size and sink activity (Wareing and Patrick, 1975). The sink activity is again sub-divided into two components and they are the GFD and GFR (Pearson and Hall, 1984). The duration of the reproductive growth period is very important because number of grains for plants are determining during this period. It has been reported that numbers of spikelets per ear in cereal crops can be increased by increasing length of the reproductive growth period (Yoshida, 1972). The data are furnished in Table 4, which indicated that the sink capacity decreased (-19.1%) under 100% PE compared to 125% PE level of drip irrigation. But, the values showed increasing trend with increase in fertilizer levels (75% RDF: 682.84 to 125% RDF: 749.0 gm^{-2}). Nevertheless, drastic decline in the sink capacity could be compensated when supplemented with the fertigation. The sink size, that is, the spikelet number per unit area (Yoshida, 1981) was also reduced with deficit and excess water availability situations (-13.2 and -5.7% in 100 and 150% PE levels respectively as against 125% PE) but compensated fairly well with fertigation practice. Grain filling, a crucial determinant of grain yield in rice crop, is characterized by duration and rate of filling (Yang et al., 2008). Grainfilling period is the duration from anthesis to physiological maturity and beyond. The GFD showed variations with the values ranging from 25.4 (100% PE) to 27.1 (150% PE) for water treatments. In the case of fertilizer levels, the GFD increased with increase in RDF levels.

However, the reduction in GFR was found to be phenomenal with the lesser water availability treatment (100% PE: -34.4%) in comparison with the moderate water supply (125% PE). Influence of fertigation was phenomenal in safely narrowing down such reduction in GFR values. This signified that between the two components of sink activity, the GFR played a vital role for panicle weight and grain yield increase especially in less water applied + fertigation practice. This was in corroboration with the findings of Mohandass et al. (1988) showing that the GFR possessed significant positive association (r = 0.953**) but the duration exhibited poor correlation (r = 0.278) with the grain yield under lowlight stress environment. Studies on the contribution of GFD and GFR to grain yield in rice on a panicle basis further showed that the grain yield of different genotypes was mainly determined by GFR (Cho et al., 1987; Jones et al., 1979).

Source-sink limitation

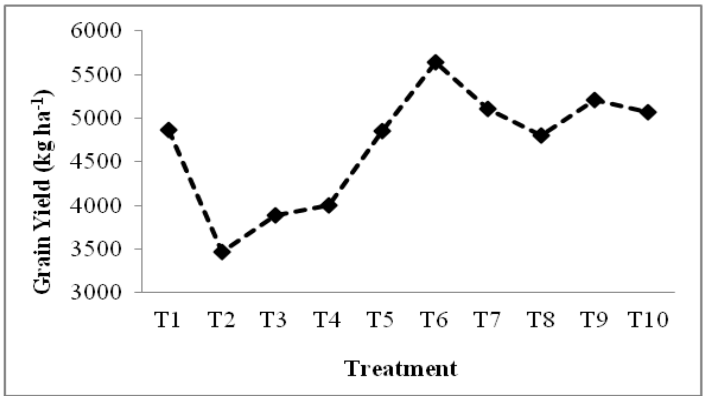
An attempt has also been made to explain yield variations in the chosen drip fertigation treatments in terms of source- and / or sink-limitation. The results of the Table 5 indicated that though the sink-source ratio was higher with moderate level of water (125% PE) and fertilizer (100% RDF) supply, the differences due to drip fertigation treatments were less appreciable.

On the contrary, the Sa values increased steadily from 100% (0.602) to 150% (0.985) PE level of drip irrigation. In the case of fertilizer levels, higher Sa (0.910) was observed at 125% RDF level. Thus, the values of Sa was centering around 1 especially for the medium and higher water supplying (125 and 150% PE levels) treatments, which in the scale of 0 - 1 of Gifford et al. (1973) explained that all additional assimilates produced was fully used up by the developing grains, and thus the grain growth was entirely source-limited in these water treatments. However, no solid conclusion could be arrived at in respect of the fertilizer levels tried, meaning that detailed studies are required in future to unravel the mystery.

Contribution to grain yield in cereal crops had conventionally been assessed using yield per plant and various yield attributes, consequently ignoring the function of other organs such as ear awns and flag leaf. These plant parts considerably affect grain yield and its attributes during grain filling stage (Ahmed et al., 2004;

Table 5. Variations in source-sink limitation due to drip fertigation in aerobic rice.

Treatment	Sink / Source ratio (Sink limitation)	Sa (Source limitation)
Irrigation regime		
100 % PE	0.905	0.602
125 % PE	0.907	0.847
150 % PE	0.813	0.985
Fertilizer regime		
75 % RDF	0.868	0.794
100 % RDF	0.904	0.786
125 % RDF	0.831	0.910
Conventional practice	0.718	0.982



T_1: Conventional method		
T_2: 100 % PE + 75 % RDF	T_5: 125 % PE + 75 % RDF	T_8: 150 % PE + 75 % RDF
T_3: 100 % PE + 100 % RDF	T_6: 125 % PE + 100 % RDF	T_9: 150 % PE + 100 % RDF
T_4: 100 % PE + 125 % RDF	T_7: 125 % PE + 125 % RDF	T_{10}: 150 % PE + 125 % RDF

Figure 3. Grain yield as influenced by drip fertigation treatments in aerobic rice.

Khaliq et al., 2008). The grain yield of rice is often influenced by sink capacity rather than source strength under stress-free environment (Fukai et al., 1991). Higher grain yield of 5643 kg ha^{-1} was registered with the drip fertigation practice at 125% PE + 100% RDF level. Similar observation of yield reduction was noticed in both the low water as well as fertilizer supplying treatments**.** The reduction in grain yield due to deficit water supply was more (27.2 %) in 100% PE as compared to 125% PE level respectively (Figure 3).

Conclusion

Summarizing the influence of drip fertigation system on sink characteristics in aerobic rice, it could be inferred that the yield variations observed under varied water as well as fertigation levels could be mainly due to the alterations in sink capacity and its activity. Again, the major component of sink activity, *viz*., grain filling rate was greatly influenced by water and fertilizer levels. This indicated that further crop improvement and management strategies intended for stabilizing the yield under aerobic environment should be aimed at stabilizing the sink capacity and grain filling rate. These findings also suggested that in this source-limited rice crop, future strategies should be aimed at developing efficient plant type and management options ensuring the capability of not only synthesizing more biomass under aerobic environment but also to partition it more towards 'sink', that is, the developing grains. The performance of the aerobic rice grown with the drip fertigation practice scheduled at 125% PE with 100% RDF level was found to be superior for most of the source sink characters and grain yield. Our results confirm the feasibility of growing aerobic rice under drip fertigation system.

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Full Length Research Paper

Studies on the epidemiology of white rust and Alternaria leaf blight and their effect on the yield of Indian mustard

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High severity of white rust and Alternaria leaf blight diseases is an important constraint in the production of Indian mustard. An experiment was conducted at the Regional Research Station, Gurdaspur during *Rabi*, 2011 to 2012 to investigate the role of weather conditions like humidity, temperature and rainfall on these diseases and to measure the loss in yield due to them. The first visible symptoms of white rust first appeared 42 days after sowing while those of Alternaria leaf blight appeared at 61. The development of white rust and Alternaria leaf blight was favoured by a mean temperature ranging between 11.4 to 17.7°C and 13.5 to 19.3°C, respectively along with an average relative humidity of more than 70%. A highly significant positive correlation was observed between disease severity as well as maximum and minimum temperatures. The average loss in seed yield due to these diseases was estimated to be 36.88%.

Key words: Epidemiology, white rust, Alternaria leaf blight, mustard, yield loss.

INTRODUCTION

Indian mustard (*Brassica juncea* (Linn) Czern and Coss.) is an important oilseed crop. The crop is affected by many biotic and abiotic stresses. Among the biotic ones, white rust caused by *Albugo candida* (Pers.) Kuntze and Alternaria leaf blight caused by *Alternaria brassicae* (Berk.) Sacc. are the most destructive diseases of rapeseed mustard, which can cause high yield reduction within a short period of time. Alternaria blight can cause a yield loss of 10 to 71% (Chattopadhyay, 2008) and 32.57% (Shrestha et al, 2005). A reduction of 24% in 1000 grain weight in mustard due to Alternaria blight was reported by Kolte et al. (1987). Yield losses ranging between 23 to 54.5% due to white rust have been reported from India (Saharan et al., 1984).

Environmental factors like temperature, relative humidity and rainfall play an important role in the development of white rust and Alternaria leaf blight (Sinha and Sinha, 1992). Sangeetha and Siddaramaiah (2007) have reported that a maximum temperature of 26 to 29°C, a minimum temperature of 14 to 15°C and average relative humidity of more than 65% favour the development of these diseases. The pustules of white rust developed at a faster rate when the average relative humidity was more than 65% and average temperature was between 10 to 18°C (Lakhra and Saharan, 1991). Shrestha et al. (2005) reported that Alternaria leaf blight appeared when relative humidity was above 80% with maximum and minimum temperatures ranging between 18 to 25°C and 10 to 14°C, respectively. The present investigations were planned with the following objectives:

i) To study the effect of weather on the development of Alternaria blight and white rust.
ii) To study the effect of these diseases acting together

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Table 1. Rating scale used for scoring white rust.

Disease rating	Disease severity description
0	No symptoms on leaf.
1	Rust pustules small, scattered covering ≤5% leaf area.
2	Rust pustules covering 5.1 to 10% leaf area.
3	Typical rust pustules covering 10.1 to 25% leaf area.
4	Typical rust pustules covering 25.1 to 50% leaf area. Leaf shedding.
5	Typical rust pustules covering > 50% leaf area. Defoliation severe.

Table 2. Rating scale used for scoring Alternaria blight.

Disease rating	Disease severity description
0	No symptoms on leaf.
1	Small light brown spots scattered covering ≤5% leaf area.
2	Spots small, brown, with concentric rings, covering 5.1 to 10% leaf area.
3	Spots large, brown, irregular, with concentric rings, covering 10.1 to 25% leaf area.
4	Large, brown, irregular lesions with typical blight symptoms, covering 25.1 to 50% leaf area.
5	Large, brown, irregular lesions with typical blight symptoms, covering more than 50% leaf area.

on the seed yield.

MATERIALS AND METHODS

The experiment was conducted at Regional Research Station, Gurdaspur during *Rabi*, 2011-2012. The seed of variety RLM 619 was sown in 10 plots with a plot size of 7.5 m^2 each. The recommended agronomic practices like weeding, thinning, irrigation and protection technologies to control insect-pests were adopted.

Five plots were sprayed with fungicides as per recommendation and five plots were kept unsprayed. The first spray was applied at 75 days old crop with Indofil M-45 at 0.25% followed by a second spray with Score at 0.1%. A third spray was applied with Indofil M-45 at 0.25%. The sprays were applied at 15 days interval. The development of the diseases under natural conditions was studied on ten randomly selected and tagged plants per plot. After the initiation of the disease on leaves, the disease incidence was recorded at weekly intervals. The disease assessments were continued until there was a total defoliation in the untreated plots. The scoring scales (Tables 1 and 2) were used to assess the disease.

The formula given by Wheeler (1969) was used to calculate the percent disease index (PDI) as follows:

$$\text{PDI} = \frac{\text{Total sum of individual ratings}}{\text{Number of leaves examined} \times \text{Maximum rating}} \times 100$$

The weather data with respect to daily maximum temperature, daily minimum temperature, relative humidity and rainfall were obtained from the nearby observatory. Simple correlation was done between the disease index and weather parameters.

At harvest, the total yield per plot and 1000 seed weight was measured for both the sprayed and unsprayed plots. The loss in yield was calculated by using the formula as given below:

$$Y_L(\%) = \frac{Y_S - Y_U}{Y_S} \times 100$$

Where, Y_L = percent yield loss
Y_S = yield in sprayed plot
Y_U = yield in unsprayed plot

RESULTS AND DISCUSSION

Effect of weather on the PDI of white rust

The effect of different weather parameters on the severity of white rust is presented in Table 3. The typical pustules of white rust appeared on the leaves after forty-two days of sowing, during the last week in December. During this week, the daily maximum and minimum temperature ranged between 14.1 to 20.6°C and 3.6 to 7.1°C respectively, with an average relative humidity of more than 75%. Initially, the development of the disease was slow but after 11 weeks of sowing, the number of rust pustules and the percent leaf area affected increased significantly. The increase in disease severity reached its maximum during 16th week, when there was a mean maximum and minimum temperature of 23.2 and 12.1°C respectively with mean relative humidity of more than 75% (Figure 1). Highly significant positive correlation was observed between PDI of white rust and the mean maximum and minimum temperatures (Table 4). However, the other weather factors like rainfall and relative humidity had a negative correlation with disease severity. It was observed that the mean maximum temperature of 16.3 to 23.2°C, mean minimum temperature of 6.2 to 12.1°C with an average temperature of 11.4 to 17.7°C and an average RH of more than 70% was very favorable for the rapid spread of white rust disease. Similar observations have been

Table 3. Effect of weather parameters on the development of white rust and *Alternaria* blight.

Week	Mean temperature (°C)			Relative humidity (%)			Total rainfall (mm)	White rust		Alternaria blight	
	T_{max}	T_{min}	T_{ave}	RH_{max}	RH_{min}	RH_{ave}		PDI	% increase	PDI	% increase
1	24.7	13.6	19.1	99.0	60.7	80.1	0.0	0	-	0	-
2	23.0	10.6	16.8	99.0	57.7	78.6	0.0	0	-	0	-
3	23.6	11.3	17.5	97.9	52.9	75.6	1.5	0	-	0	-
4	20.1	9.8	15.0	99.0	66.9	82.9	12.5	0	-	0	-
5	18.0	5.3	11.6	99.0	58.0	78.7	0.0	0	-	0	-
6	18.0	3.9	11.0	99.0	57.0	78.0	0.0	0	-	0	-
7	17.5	5.7	11.6	99.0	75.0	87.1	0.0	0.2	0.2	0	-
8	14.5	5.5	10.0	97.9	87.9	93.6	59.0	0.6	0.4	0	-
9	13.7	7.2	10.4	99.0	96.7	97.9	39.0	0.8	0.2	0.4	0.4
10	14.8	5.0	9.9	99.0	99.0	99.0	0.5	1.0	0.2	0.6	0.2
11	17.4	4.3	10.9	99.0	99.0	99.0	0.0	1.8	0.8	1.8	1.2
12	16.3	6.6	11.5	99.0	88.3	93.7	0.5	5.4	3.6	2.8	1.0
13	16.5	6.2	11.4	99.0	70.9	85.0	6.0	12.4	7.0	5.6	2.8
14	17.4	8.0	12.7	99.0	90.7	93.6	6.5	17.4	5.0	7.8	2.2
15	19.3	7.6	13.5	99.0	54.4	76.3	0.0	22.0	4.6	13.2	5.4
16	23.2	12.1	17.7	94.7	56.4	75.7	7.5	40.8	18.8	20.2	7.0
17	21.8	10.3	16.2	96.7	45.0	71.0	6.5	55.6	14.8	31.6	11.4
18	24.4	14.1	19.3	92.9	52.0	72.6	0.0	63.6	8.0	48.4	16.8
19	26.8	14.4	20.6	87.1	44.1	66.0	0.0	68.8	5.2	49.6	1.2
20	31.3	18.2	24.8	85.0	42.1	63.7	0.0	69.4	0.6	49.8	0.2

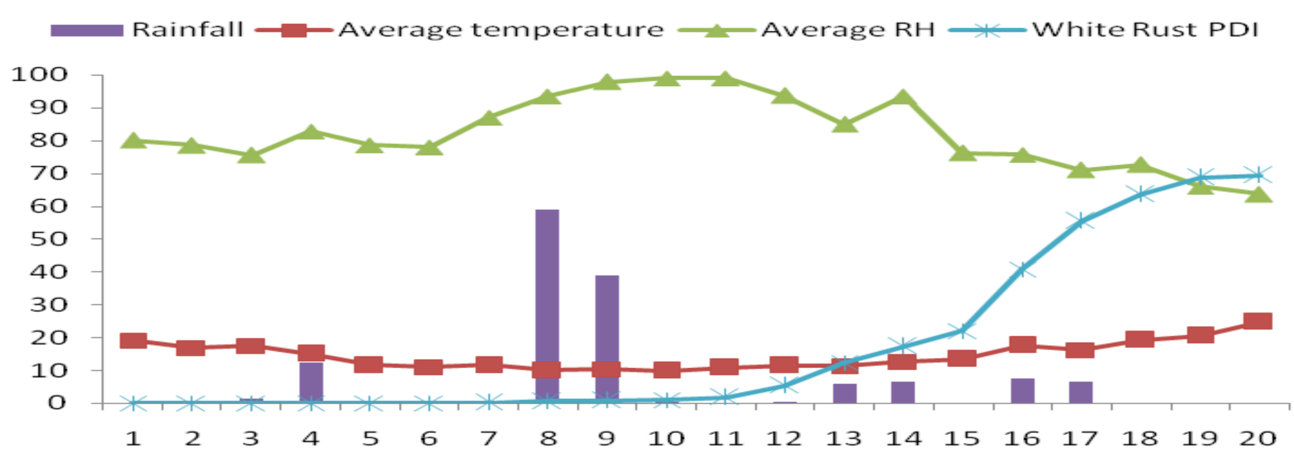

Figure 1. Development of white rust as influenced by weather parameters.

reported by Saharan et al. (1988). Lakhra and Saharan (1991) also reported that an average temperature of 10 to 18°C with an average relative humidity of more than 65% favoured the development of white rust pustules. The results were also confirmed by those of Sangeetha and Siddaramaiah (2007) who reported that the climatic conditions like minimum temperature ranging between 15 to 16°C, maximum temperature of 28 to 29°C and average relative humidity of more than 65% increased the buildup of white rust disease.

Effect of weather on the PDI of Alternaria blight

The data on the severity of Alternaria blight as affected by different weather parameters is presented in Table 3. The characteristic symptoms of Alternaria blight as small round, necrotic spots, brown to black in colour became visible on the leaves after sixty-one days of sowing. During this period (9th week after sowing), the mean maximum and minimum temperatures were 13.7 and 7.2°C respectively, with an average relative humidity of

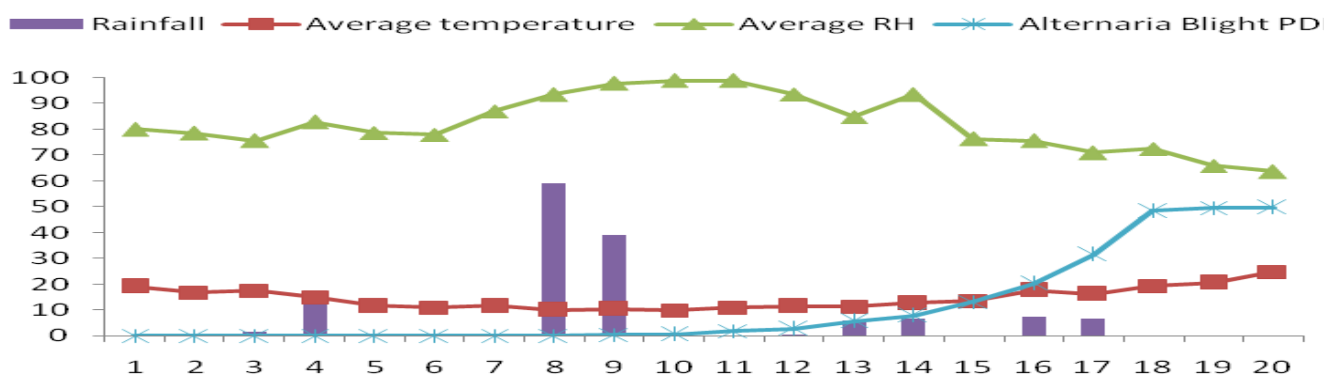

Figure 2. Development of Alternaria blight as influenced by weather parameters.

Table 4. Correlation coefficients between the weather parameters and the PDI of White rust and Alternaria blight.

Weather parameter	White rust	Alternaria blight
Maximum temperature	+0.69	+0.75
Minimum temperature	+0.72	+0.76
Average temperature	+0.72	+0.77
Relative humidity (Morning)	-0.86	-0.96
Relative humidity (Evening)	-0.60	-0.58
Average relative humidity	-0.69	-0.69
Rainfall	-0.21	-0.22

Table 5. Effect of disease severity on seed yield and 1000 grain weight.

Treatment	PDI of		Yield (kg/ha)	Yield loss (%)	1000 grain weight (g)	1000 grain weight loss (%)
	White rust	Alternaria blight				
Sprayed	18.7	9.5	1626.67	-	5.74	-
Unsprayed	71.2	49.1	1026.67	36.88	4.12	28.22

more than 90%. Total rainfall during this week was 39.0 mm which provided the wetness on the leaves. Afterwards, the disease severity increased gradually. The maximum increase in the disease severity was observed during 18th week during which the mean maximum and minimum temperatures were 24.4 and 14.1°C with an average relative humidity of more than 70% (Figure 2). There was a highly significant positive correlation between PDI of Alternaria blight and the mean maximum and minimum temperatures while, disease severity was negatively correlated with rainfall and relative humidity (Table 4). The highest intensity of Alternaria blight was noticed with a mean maximum temperature of 19.3 to 24.4°C, mean minimum temperature of 7.6 to 14.1°C, average temperature of 13.5 to 19.3°C and an average relative humidity of more than 70%. Sinha et al. (1992) associated the high severity of Alternaria blight with a minimum temperature of 8 to 12°C and high relative humidity of more than 90%. Shrestha et al. (2005) also reported that the development of Alternaria blight was maximum during the period when daily minimum temperature was between 10 to 14°C, daily maximum temperature was between 18 to 27°C and average relative humidity ranged between 60 to 96%.

Effect of disease intensity on the seed yield

Disease severity significantly affected the seed yield and 1000 grain weight (Table 5). In the sprayed plots, both the white rust and Alternaria blight progressed at a much slower rate than in the unsprayed plots. There was a total defoliation in the unsprayed plots, whereas, in the sprayed plots the leaves remained attached to the plants until senescence. The average seed yield and 1000 grain weight was significantly higher in the sprayed plots than the unsprayed plots. The loss in seed yield was found to be 36.88% and the reduction in 1000 grain weight was 28.22%. Saharan et al. (1984) reported that White rust caused a yield loss of 23 to 54.5%. A loss of 32 to 57% due to Alternaria blight in mustard has been reported by Shrestha et al. (2005). Kolte et al. (1987) reported that Alternaria blight can reduce the 1000 seed weight of mustard by 24%.

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