African Journal of Agricultural Research

Volume 10 Number 25 18 June 2015

ISSN 1991-637X

Academic Journals

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Vol. 10(25), pp. 2480-2485, 18 June, 2015
DOI: 10.5897/AJAR2014.9123
Article Number: EB8DCDA53499
ISSN 1991-637X

http://www.academicjournals.org/AJAR

African Journal of Agricultural Research

Full Length Research Paper

Fodder production, yield and nodulation of some elite cowpea (*Vigna unguiculata* [L.] Walp.) lines in central Malawi

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Received 3 September, 2014; Accepted 15 April, 2015

Cowpea is (*Vigna unguiculata* [L.] Walp.) is multipurpose legume grown for its edible grain and leaves and may be used as green manure or animal feed. The shoot biomass or fodder production of cowpea nodulation and effectiveness are seldomly considered in screening and release studies, yet such information is important for the use of the crop. A field study was therefore conducted Bunda College, (14° 35 S'; 33° 50 E', Lilongwe, Malawi in the 2012 to 2013 cropping season to evaluate the performance of eight elite cowpea lines originally from the International Institute of Tropical Agriculture (IITA), compared to two released varieties (Sudan 1 and IT82E-16) for fodder production, nodulation and grain yield and yield components in a randomized complete block design. The results showed there were significant differences ($P<0.05$) in grain yield (1.1 to 3.1 t ha^{-1}), fodder (1.1 to 3.0 tha^{-1}) plant height at flowering (25 to 67 cm), pods m^{-2} (55 to 224), seeds per pod (10-14), cumulative leaf fall (0.9 to 1.8 tha-1) and nodules per plant (9 to 21). There were no significant differences on % nodule effectiveness (mean 95%) and canopy width at flowering (mean 51 cm). The elite line IT98K-205-8 produced the highest grain yield of 3,085 kg/ha followed by the variety Sudan 1 with 3,065 kg/ha and then elite line IT98K-205-9, which produced 2,763 kg ha^{-1}. The lowest yielding elite line was IT93K-693-2 which gave 1,092 kg ha^{-1} of grain. Cumulative leaf fall accounted 31 to 94% of total fodder dry matter. Sudan 1 also had the highest nodules per plant (22) followed by IT82E-16 and IT99K1060. Estimated fodder N content was 2.4% giving 24 to 72 kg ha^{-1} as potential N in fodder. Although these lines were not selected as dual purpose, the results show opportunity for selecting dual purpose lines through evaluating for biomass. The released variety Sudan 1 notably had high grain yield, number of nodules and pods per plant.

Key words: Cowpea nodulation, biomass production, natural leaf fall.

INTRODUCTION

Cowpea (*Vigna unguiculata* L. Walp.) is an edible legume crop grown for its grain while leaves may be used as a vegetable, green manure or animal feed or as a silage crop. Cowpea grain contains 24 to 32% protein (Neil et al., 1992), and the crop is adaptable to drought (Hall, 2004). In Malawi cowpeas are important in the dry areas

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where legumes such as beans (*Phaseolus vulgaris* L.) do not do well (MoAFS, 2012). In the 2011 to 2012 season average cowpea yields were 348 kg ha^{-1}, against potential yields of 2000 to 2500 kg ha^{-1} (MoAFS, 2012). Like many legumes, cowpeas are complimentary to cereals and other non-legume crops through fixation of atmospheric nitrogen in a process called biological N fixation (Nyemba and Dakora, 2010; Snapp, 1998; Ojiem et al., 2000; Myaka et al., 2006). In Burkina Faso, Bado et al. (2006) reported that cowpeas accumulated 2.5 to 3.4 t ha^{-1} of stover containing 50 to 115 kg ha^{-1} N of which 52 to 56% was derived from the atmosphere. In soils low in phosphorus, the roots of cowpea develop effective mycorrhizal association improving the soil's available phosphorus content (Valenzuela and Smith, 2002). The roots and fallen leaves of cowpea make significant differences to subsequent cereal yields (Carsky and Vanlauwe, 2002; Bado et al., 2006). The crop forms an excellent crop cover for suppressing weeds while at the same time providing soil erosion control (Valenzuela and Smith, 2002). Cowpeas are also considered suitable as cover crops in conservation agriculture systems (Mupangwa et al., 2012). Like many legumes, cowpeas are also important in the rotation or intercropping cereal crops where cowpea serves as a trap crop by helping to reduce the seed bank of striga spp, parasitic weed of cereals (Berner et al., 1996; Kabambe et al., 2005; Carsky et al., 1994). In Malawi, several efforts have been undertaken to promote legumes for the above reasons (Ngwira et al., 2012; ICRISAT/MAI, 2000), including the national Farm Input Subsidy Programme (FISP), which included seeds of grain legumes (MoAFS, 2007; MoAIWD, 2012).

From the foregoing, it is evident that most of the non-grain uses of cowpea are related to its above ground biomass and its nitrogen fixation. Thus in order for cropping systems planners to take full advantage of the same, it is important that information on biomass and nodulation is known for pre-release or released varieties. Many screening programs do not evaluate for this (Mazuma et al., 2008; Kabambe et al., 2014). The objective of this study was to evaluate eight elite cowpea lines in an on-going cowpea project supported by the McKnight Foundation of USA for yielding ability, nodule formation and effectiveness and biomass production.

MATERIALS AND METHODS

Study location, treatments, experimental design and plots sizes

This study was conducted at Bunda College Crop and Soil Sciences Student's Research Farm during the 2011/2012 growing season. The site is 1158 m above sea level, latitude 14° 35 S' and longitude 33° 50 E'. The soil type varies from clay loam to sandy loam textural classes with medium fertility. The mean annual rainfall is approximately 1031 mm with coefficient of variation (cv %) of 16.6% indicating adequate reliability of total rainfall (Jones and Kanyama, 1975). The total rainfall l for the season under review (2011 to 2012) was 1001.7 mm. The crop received rainfall amounting to 816.5 mm between January and mid-April 2012 which was 81.5% of the season's total rainfall. This was adequate rainfall for cowpea production and distribution was also good throughout the crop growing period.

The study evaluated eight ex-International Institute of Tropical Agriculture (IITA) elite cowpea lines in comparison to two released varieties Sudan 1 and IT82E-16, out of only three released cowpea varieties in Malawi (Mviha et al., 2011). Table 1 provides a list of the treatments and their descriptions. The lines were in advanced stages of evaluation by a cowpea project at Lilongwe University of Agriculture and Natural Resources, supported by the McKnight Foundation of USA. A randomized complete block design with three replications was used. Plots comprised of 4 ridges x 4.0 m long x 0.75 m apart. The net plot areas was comprised the middle 2 ridges x 4.0 m long x 0.75 m (area = 6 m^2). Two seeds of cowpea were planted per station, spaced at 20 cm apart. The expected plant count was 13.3 plants m^{-2} or 133,000 ha^{-1}. There was no fertilizer of any kind applied to the plots. All these agronomic practices were in line with current recommendations (MoAFS, 2012). The experiment was planted on 3rd January 2012. Nodulation was based on resident bacteria in the soil, not supplementary inoculation.

Data recording and collection

Data was collected and reported on the following parameters: Plant count at harvest, plant biomass, pods per plant, 100 seed weight, number of nodules, effective nodules, canopy width and plant height. Data on plant counts and grain yield were recorded from the net plot area of 6.0 m^2. Recorded grain yield was converted to 12% storage moisture. Pods per plant were recorded from the plants harvested and expressed as pods m^{-2}. Cowpea plant biomass or fodder was the sum of periodic cowpea leaf fall collections and above ground fodder from plants at harvest. Dry leaves from free fall were collected from litter traps covering an area of 2 m x 0.75 m (1.5 m^2) in the net plot area. The traps were simply plastic sheet laid in between plant rows at 2 weeks after planting. Three collections were made at 8, 11 and 14 weeks after planting (WAP) and oven dried at 72°C for 48 h (Koide et al., 2000). Fodder at harvest was taken from all above ground plant matter from net plot area and oven-dried as above. Harvesting was done in mid-April after 100 days from planting (DAP). Average N content of fodder was determined by taking sub-samples of combined fodder from leaf fall and standing plants in all plots in each of the three replications. The sample analyzed for N using the Kjeldhal method as modified by Anderson and Ingram (1993).

Canopy width and plant height (cm) was an average five readings within the net plot. Canopy width was recorded by as linear measurement of the width of the canopy at 49 DAP (mid-flowering) only. A maximum distance of 0.75 m reflected full canopy closure, as this was the row width. Plant height was linear measurement from base to tallest upright growing point (tip) and was taken at 49 days after planting only. Number of nodules per plant was recorded as an average from four plants that were dug out per treatment and nodules found on the plants were counted. This was done when the cowpeas had just started flowering and sampling was done on borders of ridges because it was destructive sampling. Nodule effectiveness was assessed by looking at the inside color of nodules. Ten nodules from each variety/elite line were sampled, opened and color-examined. The ten nodules were randomly collected from the four plants dug out in a treatment. Those nodules with red/brown color were deemed effective and those with different colors such as green or white (lacking in leghemoglobin) were considered not effective for nitrogen fixation according to Gobat et al. (2004). Harvest index was calculated by as: [total grain yield per hectare/(total above ground biomass per

Table 1. Treatment descriptions.

Entry code	Name*	Description of seed	Days to maturity	Leaf type	Type: released or elite
3	IT 99K-491-7	Medium Unit, black eye	79	Broad	Elite
5	IT98K-503-1	Medium white, brown eye	79	Broad	Elite
24	IT99-1060	Medium brown	77	Broad	Elite
31	IT98K-205-9	Medium white, black eye	79	Broad	Elite
33	IT98K-205-8	Medium white, black eye	79	Broad	Elite
35	IT99K-1245	Medium white, black eye, segregating	74	Broad	Elite
45	IT95-1090-12	Medium brown	78	Narrow	Elite
47	IT93K-693-2	Medium brown, shrinkled	74	Broad	Elite
51	Sudan 1	Small round, cream	69	Broad	Released
52	IT82E-16	Small round, pink	70	Narrow	Released

*all 'IT…' entries are from IITA. Source of Sudan 1 not well known.

Table 2. Performance of elite lines on plant height, grain yield and yield components and harvest indices.

Cowpea entry	Plant height (cm)	Pods (m^{-2})	Pod length (cm)	Seeds no./pod	100 seed weight (g)	Grain Yield kg ha^{-1}
IT99K-491-7	54.2	101	11.40	9.67	12.47	1496
IT98K-503-1	52.6	105	10.08	8.00	12.78	1588
IT99K-1060	36.0	146	12.18	11.00	12.31	2119
IT98K-205-9	55.9	214	12.66	10.33	11.88	2713
IT98K-205-8	29.2	224	13.51	13.88	10.97	3085
IT99K-1245	33.7	60	11.94	9.67	12.81	1265
IT95-1090-12	67.1	55	10.06	8.67	11.28	1176
IT93K-693-2	25.7	77	11.81	10.67	13.36	1097
Sudan 1	25.7	179	15.81	14.33	9.44	3065
IT82E-16	67.2	160	11.68	10.00	14.43	2662
Mean	49.0	132	12.06	10.57	12.17	2117
LSD (0.05)	23.5	85.63	1.70	1.524	2.12	928.6
F Prob.	0.004	0.003	0.049	0.001	0.008	<0.001

hectare)] that is (above ground biomass + grain yield + pod weights).

Data analysis and mean comparison

Data were analyzed using the analysis of variance and regression procedure using Genstat 16 statistical package, and means were separated by Least Significant Difference (LSD) at 5%.

RESULTS AND DISCUSSION

Cowpea growth, yield and yield components

The analysis of variance showed that there were significant treatment differences (<0.05) on plant height, podsm^{-2}, pod length, seeds per pod, 100 seed weight and grain yield (Table 2). There were no significant entry effects on harvest count (mean 130,556 = plants ha^{-1}), harvest index (mean = 0.52) and canopy width (mean = 50.7 cm). The absence of significant difference on canopy width and harvest index is surprising considering that there were significant yield differences. The observed variability in plant height is expected as these are distinct lines with varying growth habits. Valenzuela and Smith (2002) noted that cowpea grows rapidly, reaching a height of 48 to 61 cm when grown under favorable conditions. On seed weight, the seed sizes of all entries was generally small in comparison to sizes of up 21 g/100 seeds reported by Omokonye et al. (2003).

On grain yield, the released variety Sudan 1 gave joint highest yield with the elite line IT98K-205-8 of about 3.0 t ha^{-1}. Only one other elite entry yielded above 2.5 tha^{-1}, along with released IT82E-16. The high yielding entries also had higher pods m^{-2}. The high yield of Sudan 1 was associated with long pod length, seed weight and plant

Table 3. Fodder biomass, cumulative leaf fall and total fodder biomass of cowpea elite lines/varieties.

Cowpea elite lines	Leaf fall 1 kg/ha 8 WAP*	Leaf fall 2 kg/ha 11 WAP	Leaf fall 3 kg/ha 14 WAP	Cumulative Leaf fall kg/ha	Total Fodder (kg/ha)	Cumulative leaf fall as % of total fodder
IT99K-491-7	597	**558**	397	1553	3021	51
IT98K-503-1	605	283	253	1141	2041	56
IT99K-1060	331	112	304	747	2046	37
IT98K-205-9	455	383	234	1072	1530	70
IT98K-205-8	262	166	129	556	1822	31
IT99K-1245	388	398	243	1029	1782	58
IT95K-1090-12	581	457	143	1180	1475	80
IT93K-693-2	808	220	64	1092	1156	94
Sudan 1	1115	472	246	1834	1931	94
IT82E-16	337	316	244	897	1502	60
Mean	548	337	226	1110	1821	-
LSD (0.05)	352.3	358.3	222.6	613.5	936.3	-
F Prob.	0.002	0.034	0.194	0.018	0.034	-

*WAP = weeks after planting.

height, but this was not true for the other entries with high grain yield. Only two of the elite lines compared well with potential yields of 2.0 to 2.5 tha^{-1} for Malawi (Mazuma et al., 2008; MoAFS, 2012; Kabambe et al., 2014). Mazuma et al. (2008) also reported that Sudan 1 and IT82E-16 were amongst high yielding entries giving yields of 1789 and 1509 kgha^{-1} respectively. Results are also comparable to those of Akande and Balogun (2009) who reported highest cowpea yields of 1737 kg ha^{-1} in a multi-locational programme in Nigeria. However, average grain yield in this study was much higher than the average yield of 750 to 1000 kg ha^{-1} in Nigeria (Omokanye et al., 2003; Kamara et al., 2008).

Leaf fall and total fodder yield

The results of leaf fall show significant entry differences for leaf fall at 8 WAP, 11 WAP, cumulative leaf fall and total biomass but not for leaf fall 3 (Table 3). The results show that Sudan 1 and IT93K-693-2 shed most leaves at leaf fall 1 while IT99K-491-7 shed most leaves at leaf fall 2. Leaf fall declined with sampling time. It is therefore likely that some of the fallen leaves could contribute to improved fertility status and yield in cropping systems involving intercropping with long season crop types. However, early leaf may not be compatible with systems aiming to use residues for animal feed or as mulch to prevent evaporation in subsequent dry months.

The highest cumulative leaf fall (1834 kgha^{-1}) came from Sudan 1, followed by 1553 kg ha^{-1} from entry IT99K-491-7. Notably, for Sudan 1 the cumulative leaf fall was 94 % of total biomass, while for the later this was 51 %. The highest fodder biomass was recorded from IT99K-491-7 (3021 kg ha^{-1}) followed by IT98K-503-1, IT99K1060 and Sudan 1 (2041-1931 kg ha^{-1}). These fodder yields are in same range as reported by Omokanye et al. (2003) and Bado et al. (2006). Of the entries in the study only two (IT99K-1060 and Sudan 1) gave yield and fodder of about 2000 kg and could be considered dual purpose. The average N content of the stover was 2.4%, thus giving potential contributions of 24 to 72 kg ha^{-1} nitrogen. The N content compares well with 2.5% reported in pigeon pea (ICRSAT/MAI 2000), but below 3.6% reported by Bado et al. (2006) in cowpeas. In general a minimal green manure rate of 2.0 t ha^{-1} is considered as agronomic threshold (ICRISAT/MAI 2000). While these entries are not purpose-bred, the results show the potential benefit of screening for the same at later stages of research programs to enrich uses of released varieties.

Nodulation

There were significant treatment differences on number of nodules per plant (Table 4), but not on % effective nodules (mean = 95.0%). The highest nodule number came from Sudan 1 (21.7 nodules/plant), followed by IT8282E-16 (18.9), IT95-1090-12 (14.42) and 1T99K-1060 (14.0) Only two entries (Sudan 1 and IT99K-1060) appear to give grain and forage yields of about 2 tha^{-1} or more and high nodule numbers. These results concur with the ranges of 3-21 nodules per plant reported by Bhuvaneswari et al. (1998). Ndor et al. (2012) showed that nodules per plant in cowpeas increased from 20 to 32 when P application was raised from 0 to 40 kg ha^{-1} P. The authors reported cowpeas yield increase from about

Table 4. Nodulation cowpea elite lines and varieties.

Cowpea elite lines / Varieties	Average number of Nodules/ Plant
IT99K-491-7	10.42
IT98K-503-1	13.17
IT99-1060	14.00
IT98K-205-9	9.00
IT98K-205-8	9.57
IT99K-1245	9.08
IT95-1090-12	14.42
IT93K-693-2	8.33
Sudan 1	21.75
IT82E-16	18.92
Mean	12.88
LSD (0.05)	7.09
F Prob.	0.01

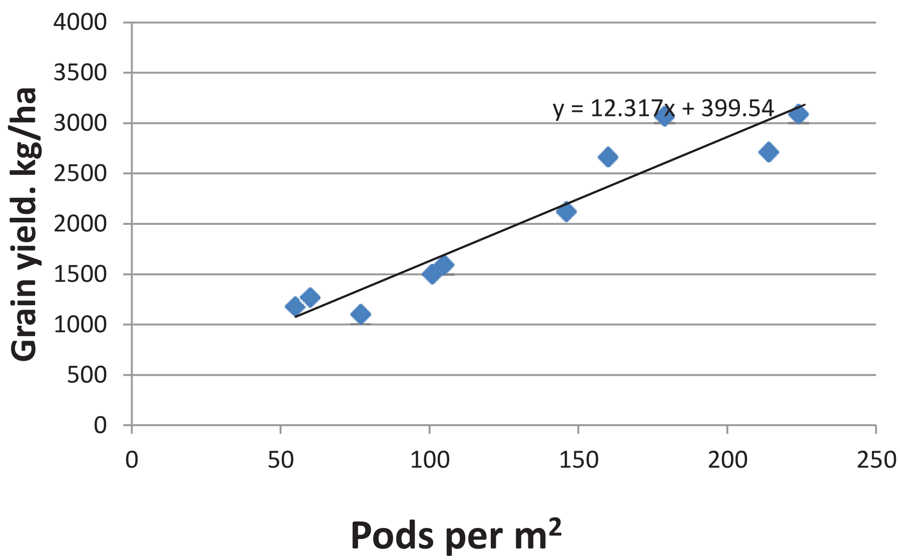

Figure 1. Relationship between podm^{-2} and grain yield.

1.0 to 1.5 t ha^{-1} with associated with the same P application rates.

General discussion

A number of regression relationships were explored, and only the grain yield and pod m^{-2} yielded a significant regression (Figure 1). This is a fitting result since pods m^{-2} is an aggregate expression of many yield components and management factors including pest control. The results from this study have also shown that elite lines IT99K-491-7, IT98K-503-1 and IT99-1060 were outstanding fodder producers at over 2 t ha^{-1}. The best fodder yield of 3 t ha^{-1} gave 1.8 t ha^{-1} grain yield. The results show that various combinations of biomass or grain yield options exist and it might be good for researchers to release a range of lines to provide for options in use.

Conflict of Interest

The authors have not declared any conflict of interest.

ACKNOWLEDGEMENT

Authors would like to acknowledge the Lilongwe University of Agriculture and Natural resources and the

McKnight Foundation for financial support to this work, and all staff of Crop and Soil Sciences of LUANAR who assisted in conducting this work.

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Vol. 10(25), pp. 2486-2493, 18 June, 2015
DOI: 10.5897/AJAR2013.8032
Article Number: F3F6EAC53501
ISSN 1991-637X

http://www.academicjournals.org/AJAR

African Journal of Agricultural Research

Full Length Research Paper

Power take-off rotation and operation quality of peanut mechanized digging

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Received 4 October, 2013; Accepted 15 April, 2015

Considering that mechanized digging is an important stage in the productive chain of peanut, the studies related to the quantification of visible, invisible and total losses are still scarce, making it necessary to investigate these losses in order to obtain the operation control. In this context, the aim of this study was to evaluate the losses mentioned and the operational performance in the mechanized peanut digging related with five rotations in the tractor power take-off (PTO), verified by statistical control of the process (SCP). The experiment was carried out in tracks with eight replications for each treatment, making a total of 40 sampling points. There was no influence of PTO rotations in the visible, invisible and total loss averages during digging. The PTO rotation in 378 rpm (6.3 Hz) presents smaller variability of visible, invisible and total digging losses. The lowest fuel consumption variability and average speed are obtained with 486 rpm (8.1 Hz) and 378 rpm (6.3 Hz) PTO rotation, respectively.

Key words: *Arachis hypogaea* L., harvest losses, vibratory treadmill, control charts.

INTRODUCTION

In Brazil, peanut (*Arachis hypogaea* L.) cultivation has expanded, influenced by mechanization, from sowing until harvesting and the São Paulo state is the greatest Brazilian producer; accounting for about 80% of production (Santos et al., 2013). Most peanut production occurs under highly intensive conventional tillage systems (Jackson et al., 2011). According to Jackson et al. (2011), growers can experience yield loss when switching from peanut conventional tillage to strip-tillage in certain soil types due to the lack of an elevated bed at harvest time. In São Paulo it is common its utilization in areas of sugar cane renovation under conventional tillage systems. Mechanized harvesting of peanuts in Brazil is recent and has more losses compared with other crops. Peanut digging losses are inevitable, reaching higher levels with compacted soil and lower soil water content, with weak peduncle because of maturation excess, and premature defoliation caused by diseases (Roberson, 2008). Among the factors affecting digging stand out: the digger, knife sharpening, cut depth, the vibration in the shaking conveyor, and the relation between the forward speed and the treadmill speed. The incorrectly determined peanut maturity at harvest can lead to high economic losses for farmers and the peanut industry as a whole (Rowland et al., 2006).

The mechanical loss, termed digging loss, is the retention of pods in the soil during the digging process due to separation of the pod from the stem attached to

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the plant (Rowland et al., 2006). Digging losses have been estimated to be 8% of the total yield but can reach 40% at dates beyond optimal maturity (Young et al., 1982; Lamb et al., 2004). In Brazil some authors have used the statistical control of the process to identify harvest losses using the variables evaluated as quality indicators, whose tools to identify the nonrandom causes are usually the control charts (Cassia et al., 2013; Peloia et al., 2010).

Given the above, it is presupposed that the change of rotation in the tractor power take-off (PTO) can influence the digger performance, affecting the quality of operation, considering that there is a manufacturer indication to work with rotation in PTO below 540 rpm (9.0 Hz). This study aimed to evaluate the operational quality of the peanut mechanized digging with five rotations in PTO, was used as quality indicators the digging losses and operational performance of the mechanized set.

MATERIALS AND METHODS

The experiment was carried out in the experimental area of the Machines and Agricultural Mechanization Lab of UNESP/Jaboticabal, in the state of São Paulo, Brazil, at 21°14' S and 48°16' W, with average altitude of 560 m, average slope of 4% and climate Cwa (subtropical), according to the Köeppen classification. The soil of the experimental area is classified as Oxissoil. The rainfall and average temperature during the experiment were 141.1 mm and 21°C, respectively.

The soil tillage was conventional, with one plowing and two harrowing, and the peanut sowing was performed in 10th November, 2011 with a pneumatic fertilizer seeder in spaces of 0.9 m between lines, using 18 seeds m^{-1}; the cultivar used as Runner IAC 886 (Virginia Group). The digging operation was performed in 30th March, 2012, using one digger mounted 2x1 (two lines and one windrow), model C-200, pulled by a tractor model BMi 125, 4x2 TDA with power of 91.9 kW in rotation of 38,33 Hz (2300 rpm) in engine.

The experimental design was in tracks, with five rotations of PTO: 324 rpm (5.4 Hz), 378 rpm (6.3 Hz), 432 rpm (7.2 Hz), 486 rpm (8.1 Hz) and 540 rpm (9.0 Hz); defined by the variation of engine rotations (20.0, 23.3, 26.7, 30.0, 33.3 and 38.3 Hz, respectively), and eight replications. Consequently, the variation of PTO rotation promoted alterations in the rotation of shaking conveyor of the digger (1.5, 1.7, 1.9, 2.1 and 2.3 Hz, respectively). By the digging operation, the losses (visible (VDL), invisible (IDL) and total (TDL)), the fuel consumption and the average speed were evaluated.

The losses were evaluated by using a metal frame of 2 m² (1.11 x 1.80 m). This measure of the frame was determined for reaching the exact width of the digger, being placed on two peanut lines. The visible digging losses (VDL) consisted in the collect of all pods and peanut seeds found in soil surface after the digging operation, and the invisible losses (IDL) are the pods found under the soil surface, in the same place of evaluation of the visible losses. The sum of these two losses results in the total digging losses (TDL). For the determination of fuel consumption was performed using a flowmeter, comprising of two flow meters installed in series with two temperature gauges for monitoring the flow and return of the injection pump. Displacement speed values were obtained by the radar unit located on the right side of the tractor, forming an angle of 45° with the ground.

During the harvesting, soil samples were collected in layers from 0 to 0.15 m, in all sampling points, for the characterization of the soil water content. It was also collected 30 pods for the characterization of the pods water content. The characterization of yield was performed by the collect of one sampling point for each rotation evaluated. It was quantified by the sum of all totally developed pods taken off the plants, including the visible and invisible digging losses. The characterizations were performed after the digger passage.

The samples of soil, losses, pods and yield were sent to the lab for the determination of mass in digital balance, with precision of 0.01 g. Afterwards they were taken to an electric oven, in a temperature of 105 ±3°C, during 24 h, for obtainment of the dry masses. All the samples went through a sieving before the weighing, for the detachment of the soil in the pods. The samples of losses and yield were corrected to 8% (water content of peanut storage). The characterization of pods maturation was performed by Hull Scrape method (Williams and Drexler, 1981), with the collect of 200 pods in 10 random chosen plants in the studied area. The characterization of water content, in the soil and in the pods, maturation and yield presented approximate values of 26.68, 55.48 and 74.37%, 2.43 Mg ha^{-1}, respectively.

The results were submitted to descriptive statistics analysis to the calculus of central tendency measures (mean and median), dispersion measures (range, standard deviation and variation coefficient), measure of skewness and kurtosis. The Anderson-Darling test was performed in order to verify the normality of data or the need of transformation for normalization. The variables transformed were those that presented non-normality distribution, being transformed through the function: $y=1/\sqrt{y}$.

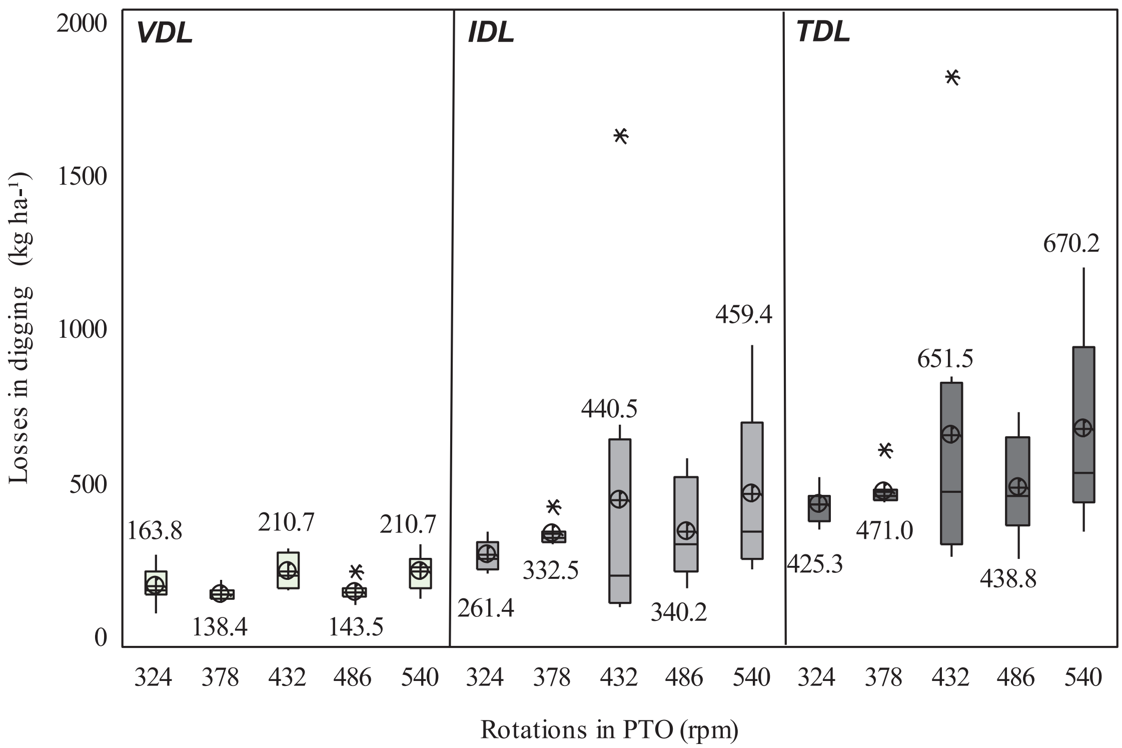
The averages were compared by Tukey test to 5% of probability, when there was significance in the variance analysis (Snedecor F test to 5% of probability). The averages were represented by box plots, that illustrate the variability and the symmetry of the data set; the presence of outliers was indicated by (*). The box plot can be indicated to the comparison of two or more data group located inside a variable. It helps in the interpretation of the behavior of a data group based in descriptive parameters, like median (Q2), lower quartile (Q1), upper quartile (Q3), interquartile range (IQR = Q3 - Q1), and the maximum and minimum values.

The results were also evaluated by statistical control of process, using control charts, type I-MR (individual value and moving range), that have central lines (general average and mean range), as well as the upper and lower control limit, defined as UCL and LCL. These limits were calculated based on variables standard deviation (for UCL, average plus three times the standard deviation, and for LCL, average minus three times the standard deviation, when bigger than zero). These charts were used in order to identify the non-randomness caused by some external factor, and to evaluate the operation quality, using as quality indicators the variables described above.

RESULTS AND DISCUSSION

Descriptive and variance analysis

In the analyzed variables there were outliers that can be seen in the box plots. These results were kept in all the statistical analysis performed, once that these outliers are part of the process and can help to identify the occurrence of non-random causes. The variables referring to the losses (Figure 1) presented non-normality distribution by the Anderson-Darling test. This asymmetry was also indicated for the VDL variable that presented positive skewness coefficient, demonstrating that the



Variable	χ	R	σ**	Median	Sc	Kc	VC (%)	AD
VDL	173.5	220.1	55.2	154.7	0.72	- 0.39	31.83	S
IDL	366.9	1530.2	269.3	309.0	3.02	11.86	73.42	S
TDL	540.4	1562.6	284.6	452.1	2.80	10.02	52.66	S

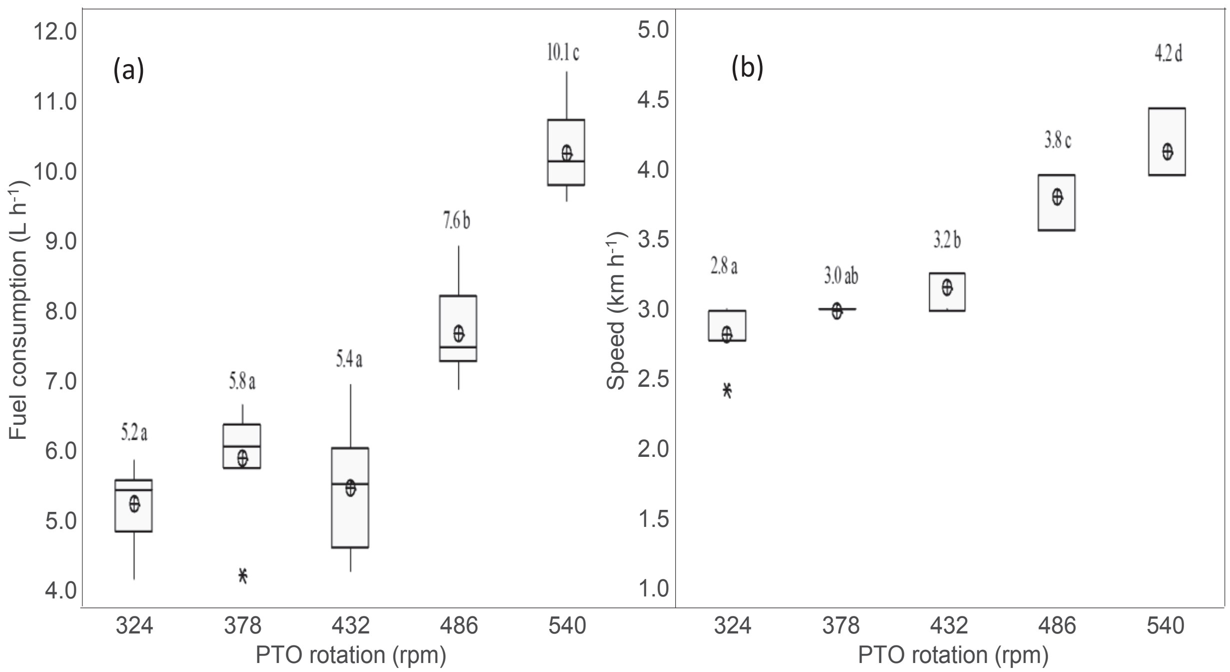
χ – mean; R – range; σ** – standard deviation; Sc – skewness coefficient; Kc – kurtosis coefficient; VC – variation coefficient; AD – Anderson-Darling Normality Test (N: normal distribution; S: skew distribution). * The absence of letters for each PTO rotation indicates that the averages do not differ by the Tukey Test 5% of probability.

Figure 1. Descriptive statistic and Tukey Test for the visible (VDL), invisible (IDL) and total (TDL) digging losses related to rotations in PTO.

mean is higher than the median; therefore, the results tend to concentrate below average. Besides, the negative kurtosis coefficient shows the existence of a platykurtic distribution curve. For the variables IDL and TDL it was verified the positive coefficients of skewness and kurtosis. The last one is represented by high values that characterize a more elongated distribution curve, in relation to the normal distribution curve. The rotations of 432, 486 and 540 rpm showed larger interquartile intervals for VDL and TDL, what indicates larger variability of these data sets. On the other hand, the same rotations in PTO to VDL presented smaller intervals, evidencing smaller variability for this variable. The smallest interquartile distance for VDL, IDL and TDL was found for the rotation in PTO in 378 rpm.

In the treatments evaluated there was no difference in losses (VDL, IDL, TDL) in function of the PTO rotation, what can be explained by the very high values of variation coefficients and the ranges. The manufacturer recommendation to work below 540 rpm in PTO, reaching 350 rpm in PTO, cannot be supported because there is no difference of the digging losses to the different tested rotations.

The fuel consumption (Figure 2a) presented non-normality distribution according to the Anderson-Darling test. The distribution presented positive skewness coefficient and negative kurtosis coefficient, indicating that the curve is more elongated to the right and more flattened in relation to the normal distribution curve, respectively. For the fuel consumption variable there was difference in treatments, the PTO rotation in 540 rpm showed the highest consumption, followed by the rotation of 486 rpm, and other treatments there was no difference in the results. It was observed that increasing the engine rotation there was also an increase in fuel consumption because of the power demand of the digger-tractor set; it is evidenced by the engine characteristic curve. According to Márquez (2011), minimum specific consumption of an engine is obtained at an operating point close to the maximum torque, that is, with less rapid



Variable	χ	R	σ**	Median	Sc	Kc	VC (%)	AD
Consumption (L h^{-1})	6.83	7.09	1.97	6.15	0.73	- 0.54	28.95	S
Speed (km h^{-1})	3.40	2.10	0.56	3.27	0.48	- 0.93	16.47	A

χ – mean; R – range; σ** – standard deviation; Sc – skewness coefficient; Kc – kurtosis coefficient; VC – variation coefficient; AD – Anderson-Darling Normality Test (N: normal distribution; S: skew distribution). * The absence of letters for each PTO rotation indicates that the averages do not differ by the Tukey Test 5% of probability.

Figure 2. Descriptive statistic and Tukey Test for the fuel consumption (a); and forward average speed (b) in peanut digging related to different PTO rotations.

engine which corresponds to the nominal operating regime.

In this way, in relation to the manufacturer recommendation to work with the PTO rotation below 540 rpm, it is necessary to considerate that the machine is being used in inappropriate conditions, in spite of the losses did not differ to the evaluated rotations and the increasing of rotation had affected the fuel consumption. In the region it is common the usage of tractors with power of 91.9 kW for the peanut digging operation. Once that for higher rotation (greater consumption), there is a proximity of the great consumption point, which corresponds to the operational condition in which the point of minimum specific consumption occurs.

The forward speed average (Figure 2b) presented data set non-normality distribution, verified by the positive skewness coefficient and the negative kurtosis. It indicates that data behavior is dislocated below average and with characteristic of a flattened curve, where values tend to go farther of average. This quality indicator was greater in PTO rotation of 540 rpm. In spite of the differences observed, the increase of average speed did not result in increasing of digging losses.

Operation quality analysis

With the quality indicator (VDL, the process was kept stable, showing that only random causes influenced (Figure 3), as in the individual values charts, far as in the moving range. The PTO rotation in 378 rpm was the treatment that obtained lower standard deviation, evidenced by the control limits (UCL and LCL). It can be pointed as the rotation with the greatest operation quality. Although the process has been stable, the values verified in the individual value charts can indicate clustering and/or oscillations runs for the PTO rotation in 378 and 486 rpm. The other evaluated PTO rotations, specially in 324 rpm, presented wide variation of the control limits, what can be associated with the high standard deviation values, with the variation coefficients and with the ranges.

In relation to the evaluated rotations, the IDL presented stable behavior, confirming the non-existence of special causes inherent to the process (Figure 4). For the PTO rotations in 324 and 378 rpm the values tended to focus around the average, what can indicate lower variability of invisible losses (moving range chart), in spite of the variation coefficient, in general high, it can be associated

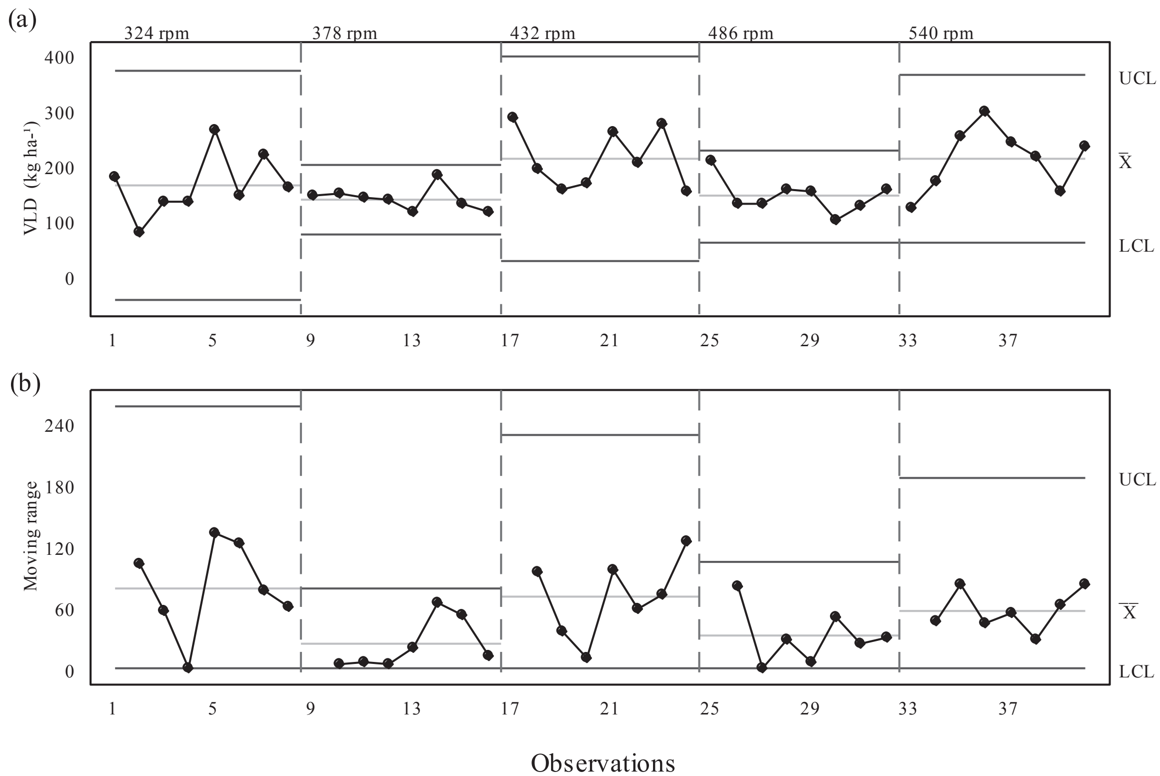


Figure 3. Control charts for visible digging losses (VDL). a) Individual values charts. b) Moving range chart. UCL: Upper control limit. LCL: Lower control limit. $\overline{X}$: mean.

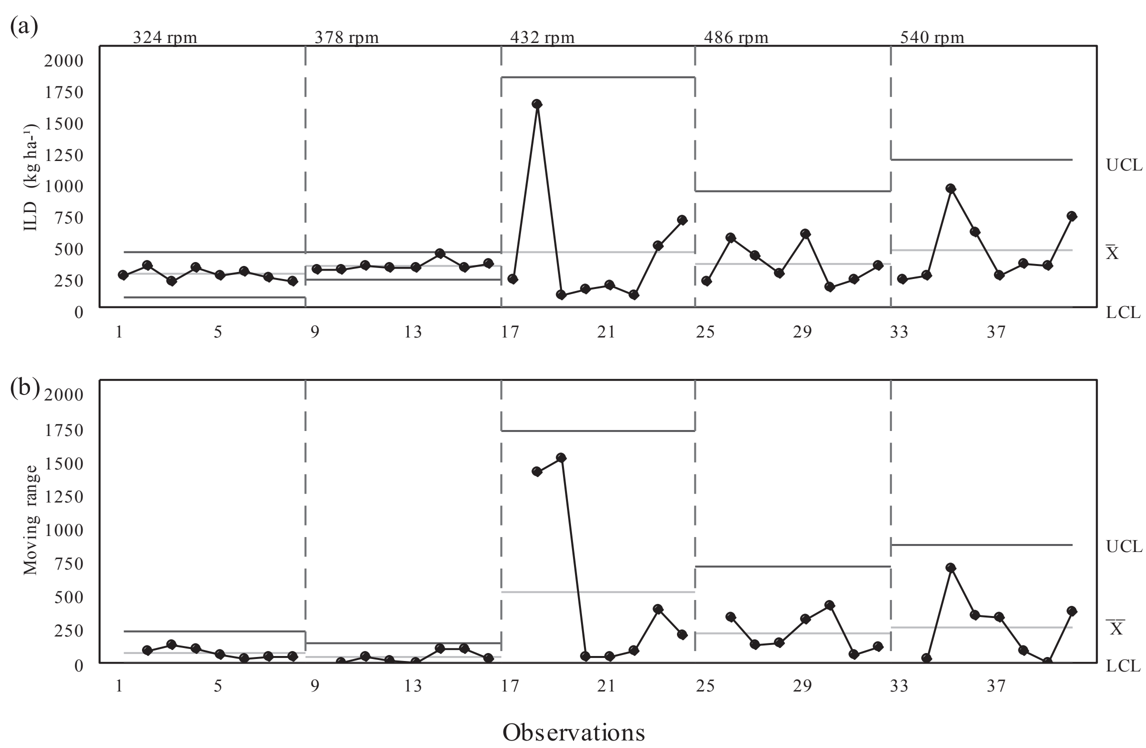


Figure 4. Control charts for invisible digging losses (IDL). a) Individual value charts. b) Moving range chart. UCL: Upper control limit. LCL: Lower control limit. $\overline{X}$: mean.

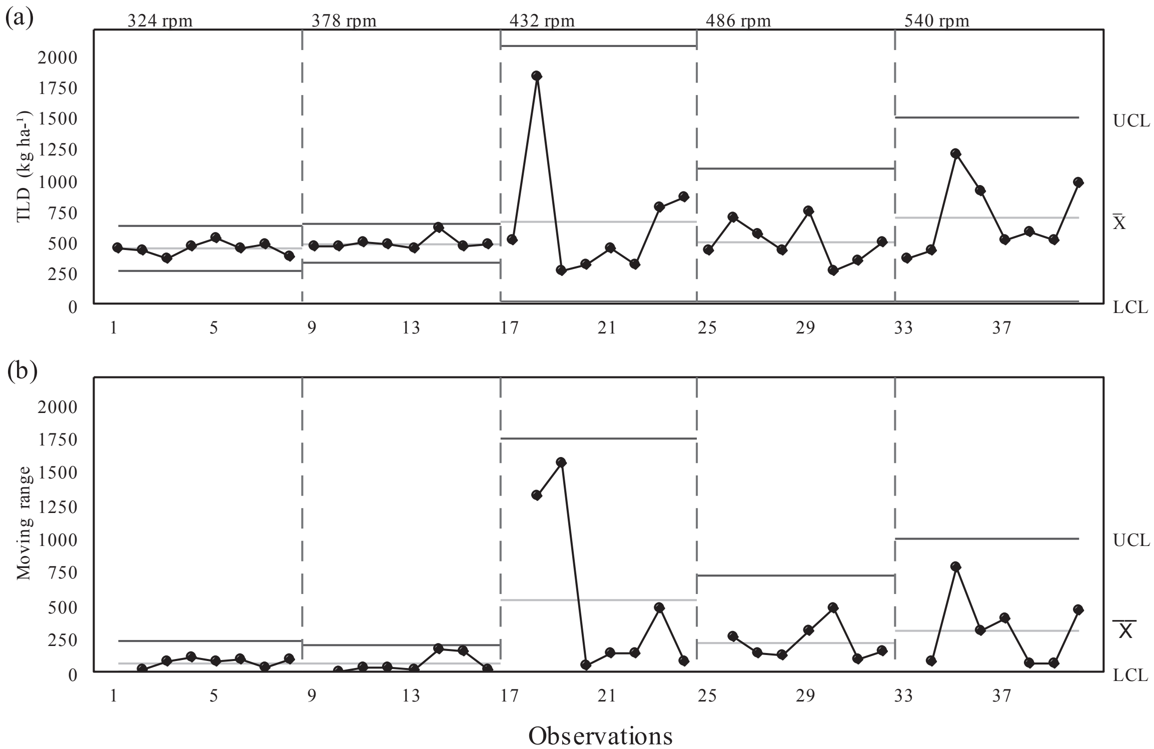


Figure 5. Control charts for total digging losses (TDL). a) Individual value charts. b) Moving range chart. UCL: Upper control limit. LCL: Lower control limit. $\bar{X}$: mean.

to the soil water content, machine regulation, appropriate PTO rotation and operation quality performed by the machine operator.

It was also observed that the PTO rotation in 432 rpm presented one isolated point of high IDL, creating a high standard deviation, consequently, the control limits were wider, overestimating the losses. In other rotations there was an increase in the variability of these losses in relation to those found in 324 and 378 rpm in PTO, which means the sampled points were more distant of the average. It can be proven by the higher standard deviation and range (in the individual value charts and moving range, respectively) and by increase the rotation of PTO, implicating in higher invisible losses.

The TDL were stable in relation to the studied rotations. According to the optic of statistical control of process, it indicates that randomness existent is intrinsic to the process (Figure 5). This variable presented similar behavior to the quality indicator IDL, what is observed in the individual value charts and moving range charts. It is explained by the fact that the IDL average was higher in relation to the VDL. When both were added, for the creation of TDL, there was greater predominance of invisible losses. This consideration can indicate that the mean cause of losses in peanut mechanized digging operation is associated to the invisible losses, independently of the rotation used in PTO, representing about 64% of total digging losses.

The PTO rotation that caused lower variability in the process, or the one that had the higher operation quality, was with 378 rpm. The TDL presented lower variability in rotation of 324 and 486 rpm in PTO in relation to the IDL, indicating that the higher operation quality for total losses in peanut digging was verified in these situations. And, they can be evidenced in the variation process chart (moving range). In others evaluated rotations the variability was higher when associated with the invisible digging losses. For the fuel consumption (Figure 6) the process can be considered stable, once that there was no existence of point above or below the upper and lower limits of control, indicating the absence of special causes. For the evaluated rotations, the data may have suffered the clustering effect around the average, in some points. It can be verified by the individual value charts, and it can influence in possible variations throughout the process. As the engine rotation is altered it is noticeable the increase of fuel consumption, because the machine needs more power to work and keep the desirable speed.

The PTO rotation that presented the lowest variability in the fuel consumption variable is in 486 rpm, according to the moving range chart. Although the fuel consumption to be higher in this rotation, in relation to the manufacturer

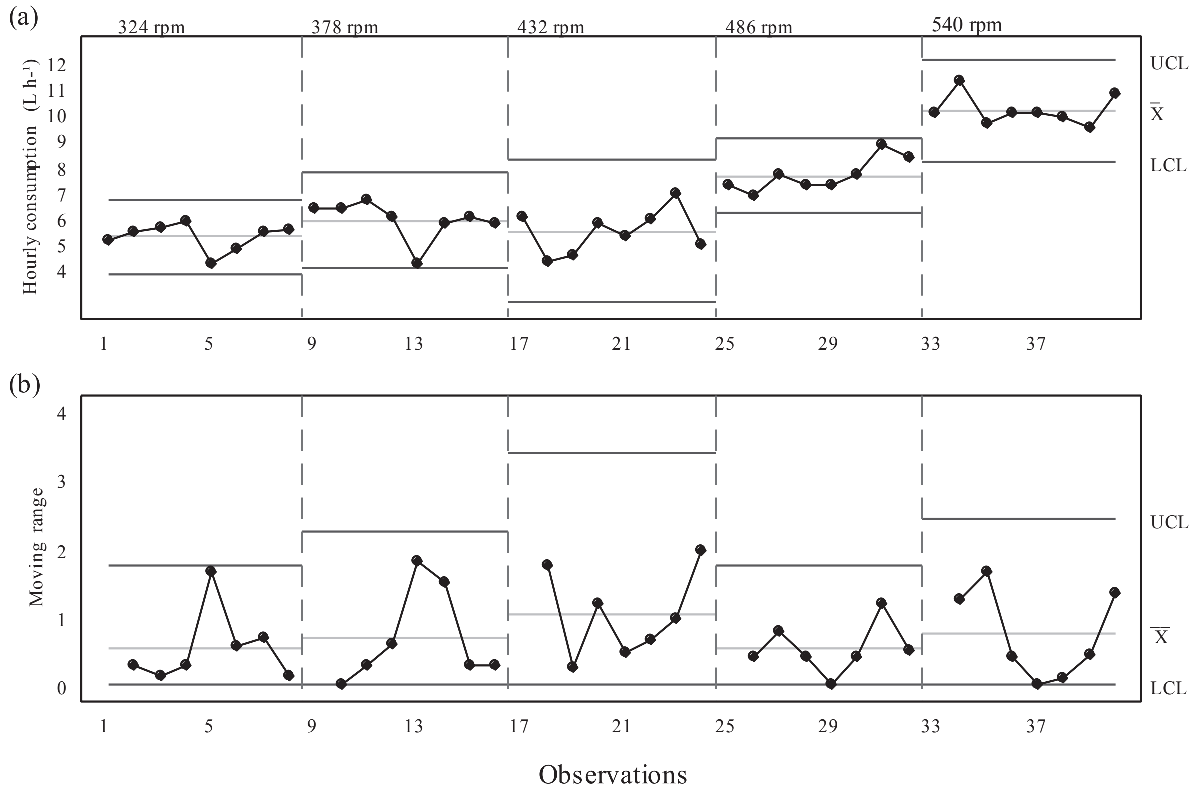


Figure 6. Fuel consumption control chart. a) Individual value charts. b) Moving range chart. UCL: Upper control limit. LCL: Lower control limit. $\overline{X}$: mean.

recommendation, it is possible that the digging operation reaches the best operation quality, in function of this variable, working in this rotation in PTO, equivalent to 1800 rpm in engine. On the other hand, the PTO rotation in 540 rpm presented, on average, higher fuel consumption (individual value charts), what can be associated with elevated variability of forward speed, for this rotation studied.

The analysis that was done by the individual value charts and the moving range charts, for the quality indicator forward speed average (Figure 7), presented instable behavior, indicating the presence of non-random causes, inherent to the process, only in PTO rotation in 324 rpm. The presence of non-random causes in the process can be explicated by clustering of points verified in the individual value charts. These points can affect the process behavior unpredictably, precluding the presence of reliable standard values for this treatment. The non-random causes can occur with variations of controllable, or notable, nature, being clearly identified. Thereby, these variations can result in function of the special causes (machine, raw material, measure, method, labor and environment).

The possible explanation for this point out of control can be associated to the factors: machine and environment. These factors can be explained in association, because it is possible that there was excess of tractor slippage, caused by the soil resistance to the cut done by the knives of the digger, or the intense traffic of machines, what would possibly provoke the speed loss of the mechanized set.

In other evaluated rotations, the process remained stable, with the presence of random causes, due the natural variability. It is interesting to observe that for the rotation of 378 rpm in PTO there was not variation resulting from the process, which means that the higher operation quality, in function of the forward speed average, was observed in this situation, since that there was no speed variation through the plot. Despite the equality of digging losses, when evaluated in different PTO rotations, the fact that the mechanized set works in the rotation of 540 rpm enabled a higher forward speed average, what reflect in the increase of the field operational capacity. In contrast it must be taken into account that with the speed increase, the straw may accumulate, because of the greater flux of vegetal material in the shaking conveyor. It is possibly explained by the lack of synchronism between the shaking conveyor speed and the forward speed of the mechanized set.

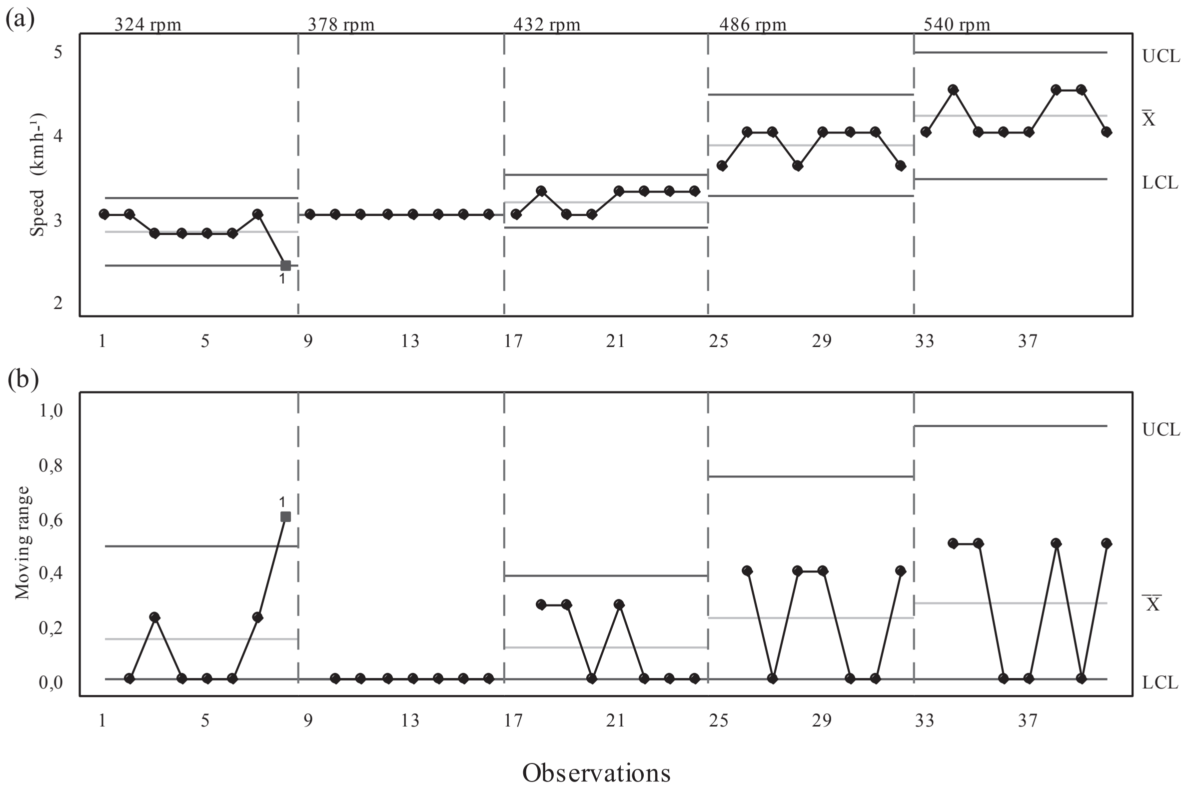


Figure 7. Control chart of forward speed average. a) Individual value charts. b) Moving range chart. UCL: Upper control limit. LCL: Lower control limit X̄: mean.

Conclusions

The PTO rotation of 378 rpm (6.3 Hz) presents lower variability in the visible, invisible and total digging losses, and there was no influence of PTO rotations in the averages of the visible, invisible and total digging losses. The lower variability of fuel consumption is obtained when it is used rotation of 486 rpm (8.1 Hz) in PTO. The forward speed average presents higher operational quality in the rotation of 378 rpm (6.3 Hz) in PTO. The fuel consumption and the forward speed average are greater in the PTO rotation in 540 rpm (9.0 Hz).

Conflict of Interest

The authors have not declared any conflict of interest.

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Vol. 10(25), pp. 2494-2500, 18 June, 2015
DOI: 10.5897/AJAR2013.8196
Article Number: 733EC0F53506
ISSN 1991-637X

http://www.academicjournals.org/AJAR

African Journal of Agricultural Research

Full Length Research Paper

Management of spot blotch of wheat using Fungicides, Bio-agents and Botanicals

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Received 4 November, 2013; Accepted 20 May, 2015

Experiments were conducted to know the effect of recommended dose of fungicides (Propiconazole, Carbendazim and Hexaconazole), bio-agents and botanicals on incidence and severity of spot blotch disease and seed yield of wheat. Two sprays of Carbendazim at 0.1% at tillering and boot leaf stage resulted in the maximum reduction in spot blotch incidence and severity followed by two applications of Propiconazole at tillering and boot leaf stage. Propiconazole was also found to be quite effective in reducing the level of disease and enhancing crop yield followed by Carbendazim and Hexaconazole. However, Carbendazim, Propiconazole and Hexaconazole were almost equally effective against spot blotch of wheat and may be used as an alternative to each other for management of disease. Two applications of Carbendazim at tillering and boot leaf stages resulted in highest grain yield. Out of the two bio-agents tested against spot blotch of wheat under field conditions, *Pseudomonas fluorescence* followed by *Trichoderma harzianum* resulted in the highest reduction in disease incidence. However, both of these bio-agents were comparatively less effective in minimizing the disease as compared to chemical fungicides. Out of four plant extracts two applications of aqueous Eucalyptus leaf extract at tillering and boot leaf stage resulted in the highest wheat yield as compared to other botanical extracts.

Key words: Fungicides, bio-agents, *Pseudomonas fluorescence*, botanicals, *Bipolaris sorokiniana*, spot blotch, *Triticum aestivum*.

INTRODUCTION

The world's population is increasing by one billion in every 11 years and at the present rate, it is expected to be 8.5 billion by the year 2025. The demand for wheat will grow faster than any other major crop as it is estimated that around 1,050 mt. of wheat will be required globally for ever growing population by 2020 (Kronstad, 1998), while Indian demand will be between 105 to 109 million tonnes (Shoran et al., 2005). To fulfill the demand of wheat for rapidly increasing population, emphasis should be given to minimize the crop losses due to several diseases, insect pests and terminal heat at the time of anthesis. Grain yield reductions due to spot blotch are variable but are of great significance in warmer areas of South Asia (Saari, 1998; Sharma and Duveiller, 2004). On an average, a South Asian country looses 20% of crop yield through leaf blight disease (Saari, 1998).

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Among all the diseases, spot blotch of wheat is considered as one of the most important disease in environments which are characterized by high temperature (coolest month greater than 17°C) and high humidity (van Ginkel and Rajaram 1993). However, it is also gradually instigating serious concerns among places with irrigated, low rainfall and temperate growing conditions (van Ginkel and Rajaram, 1993; CIMMYT, 1995). Globally, an estimated 25 million hectares of wheat cultivated land is affected by spot blotch disease (van Ginkel and Rajaram, 1998). Indian subcontinent has 10 million ha of affected land, out of which India alone has 9 million ha, most of which is in the rice-wheat cropping system (Nagarajan and Kumar, 1998). The widely applied rice-wheat cropping system of South Asia provides favourable environment for the survival and multiplication of foliar blight pathogens because rice serves as a host for the spot blotch fungi and rice stubble plays its role as a substrate for the fungi after rice harvest (Saari, 1998). Nowaday, the peasants are moving towards organic farming to reduce the hazards due to chemical residues present in the end product due to massive use of chemical pesticides for controlling the spot blotch of wheat. Natural resistance of wheat towards this pathogen is found to be low (Agarwal et al., 2004). However, there is a possibility of biological control of this disease (Mandal et al., 1999). Use of fungicides has proven useful and economical in the control of spot blotch (Viedma and Kohli, 1998). The Triazole group Propinazole especially have proven to be very effective against spot blotch disease. Keeping in view these facts an experiment was conducted for two crop season i.e. in 2008-2009 and 2009-2010 to test the efficacy of certain potential fungicides, botanicals and bio-agents against spot blotch disease of wheat so that to come up with a suitable integrated management practice for this disease.

MATERIALS AND METHODS

Experimental design

The experiments were carried out on crop research centre (CRC) of Sardar Vallabhbhai Patel University of Agriculture and Technology, Modipuram, Meerut, during the crop season 2008–2009 and 2009–2010. Bread wheat (*Triticum aestivum* L.) was sown in November of 2008 and 2009 at a seed rate of 100 kg ha^{-1} with a commercial seeder. Ten treatments were used, which included untreated control as water spray (check), foliar application with fungicides viz. Propiconazole, Carbendazim, Hexaconazole at 0.1%, bio-agents *Trichoderma harzianum* and *Pseudomonas fluorescence* at 10 g/L water and botanicals *Eucalyptus* leaf extract, Garlic clove extract, Neem leaf extract and Neem cake extract at 0.5% of aqueous solution were used.

Preparation of aqueous solution

Preparation of aqueous Garlic extract (AGE)

Two hundred gram fresh raw garlic clove were chopped and ground to prepare fine paste. This paste was soaked overnight in 200 ml distilled water. This was filtered using fine muslin cloth. The filtrate obtained served as aqueous solution for further use at desired concentration.

Preparation of aqueous Neem cake extract (ANCE)

Freshly collected 200 gram neem cakes were crushed into fine powder with help of mortar and pestle. The fine cake was soaked overnight in 200 ml of water. This was filtered using fine muslin cloth. The filtrate obtained served as aqueous solution for further use at desired concentration.

Preparation of aqueous Eucalyptus leaf extract (AELE)

Two hundred gram freshly collected eucalyptus leaves were crushed with the help of mortar and pestel to prepare fine paste .The paste was soaked overnight in 200 ml distilled water. This was filtered using fine muslin cloth. The filtrate obtained surved as aqueous solution for further use at desired concentration.

Preparation of aqueous Neem leaf extract (ANLE)

Method of aqueous extract of Neem leaf was similar as in case of eucalyptus leaf extract. Experiments were conducted in randomized block design with 3 replications per treatment, with plots size 5 × 4 m^2. The foliar application was done with a knapsack sprayer, and spraying pressure was maintained at 300 kPa and the rate was 1000 l water ha^{-1}. The foliar applications were applied at tillering and boot leaf stages during evening time.

Disease assessments

Disease was allowed to develop from natural inoculums and epiphytotic. During the assessment of disease severity, 50 flag leaves per plot were randomly collected and were removed from the centre rows of each plot. During first and second disease rating was done by taking the per cent blighted area on flag leaf (F) and flag-1 (F-1) leaf using the rating scale as: 0 = No infection, 1 = up to 10%, 2 = 11-20%, 3 = 21-30%, 4 = 31-40%, 5 = 41-50%, 6 = 51-60%, 7 = 61-70%, 8 = 71-80%, and 9: > 80% leaf area blighted according to Singh et al. (2003) and Singh and Kumar (2005). Disease severity was assessed by determining the number of lesions per cm^2 (Table 1).

First and second value respectively represent percent blighted area on the top (flag) and second top leafs. Value 1, 2, 3, 4, 5, 6, 7, 8, and 9, respectively correspond to 10, 20, 30, 40, 50, 60, 70, 80, and 9: > 80% blighted area. The percent disease index (PDI) was calculated as per following formula:

$$PDI = \frac{\text{Sum of all disease ratings}}{\text{Total number of rating} \times \text{maximum grade}} \times 100$$

On the basis of above observation, the percent disease control (PDC) was calculated with the help of following formula:

$$PDC = \frac{\text{PDI in control -- PDI in treated}}{\text{PDI in control}} \times 100$$

Statistical analysis

Analysis of variance was performed for all the data using the statistical procedure and calculations were made after applying the test of significance for the treatment means. The data taken into percentage were first transformed into angular value and then analyzed for test of significance (Chandel, 2002; Gomez, 1996).

RESULTS

Experiments were conducted for two consecutive crop season, that is, Rabi 2008-2009 and 2009-2010, using the susceptible cultivar, PBW-343 under field conditions, to know the effect of different doses and recommended doses of fungicides, bio-agents, and botanicals on incidence and severity of spot blotch disease and crop yield. In this experiment, efficacy was tested as two spraying at different crop growth stages viz. tillering and boot leaf stage. In control (Check) plot, there was no application of any fungicides, bio-agents, and botanicals. The data is presented in Tables 1, 2 and 3.

Effect on disease incidence

During first year, the results exhibited that in check plot, disease incidence was 31.11% which was significantly higher than incidence recorded in remaining other treatments. Two applications of Propiconazole at tillering and boot leaf stage resulted in least incidence 12.06% with 68.35% reduction in the incidence. The incidence recorded due to Propiconazole was at par with the incidence recorded due to Propiconazole and Carbendazim as well. Among the botanicals and bio-agents, Eucalyptus leaf extract (27.21% incidence with 28.61% reduction) was superior over the other botanicals and bio-agents applied, but significantly there effect were non significant to each other.

During second year, the results exhibited that in unprotected crop, there was 12.40% disease incidence which was significantly higher than incidence recorded in remaining other treatments. In case of twice application of Carbendazim, that is, at tillering and boot leaf stage it resulted in least incidence 4.82% with 61.12% reduction in incidence). The incidence recorded due to Carbendazim was at par with the incidence recorded due to Hexaconazole and Propiconazole as well. Among the botanicals and bio-agents Eucalyptus leaf extract resulted in 7.96% disease incidence with 16.38% reduction. Effect of Eucalyptus leaf extract on disease incidence of spot blotch was superior among the botanicals and bio-agents but significantly, it was at par with the effect exhibited by other botanicals and bio-agents used during the course of investigation.

As per average of two years data, first year 2008-2009 and second year 2009-2010; it was observed that minimum disease incidence was recorded in crop which was twice sprayed with Propiconazole followed by two applications of Carbendazim Hexaconazole at tillering and boot leaf stages of crop. Application of bio-agents and plant based extracts were found to be comparatively little less effective in minimizing the disease incidence (Table 1).

Effect on disease severity

During first year, the results exhibited that that in unprotected crop, that is, check there was 49.62% disease severity which was significantly higher than the severity recorded in remaining other treatments. Twice application of Propiconazole, that is, at tillering and boot leaf stage resulted in least severity, that is, 27.58% with 44.42% reduction which was significantly less than the severity (30.32% with 38.90% reduction) due to two application of Hexaconazole at tillering and boot leaf stages of wheat crop, which was at par with severity (32.07% with 33.37% reduction) recorded in the crop which was twice sprayed at tillering and boot leaf stages, with Carbendazim. Two application of 5.0% Garlic clove extract at tillering and boot leaf stages resulted in 35.30% disease severity with 28.66% reduction in severity and it was significantly different than the severity recorded in the crop, which was twice sprayed with 5% Neem leaf extract where 38.65% disease severity and 22.11% reduction in severity was recorded. Two application of 1.0% *P. fluorescence* at tillering and boot leaf stages resulted in 39.05% disease severity with 21.30% reduction in severity, the effect of *P. fluorescence* on disease severity was at par with the effect of Neem leaf extract on spot blotch severity.

During second year the results exhibited that in unprotected crop, that is, check there was 20.26% disease severity which was significantly higher than the severity recorded in remaining other treatments. A two application of 0.1% Carbendazim at two stages of crop tillering and boot leaf stages resulted in 7.73% severity with 61.84% reduction in disease severity which was at par with severity, that is, 8.93% with 55.92% reduction in severity recorded in the crop where 0.1% Propiconazole was applied twice at tillering and boot leaf stages, it was again at par with severity, that is, 10.13% with 50 reduction in severity recorded in the crop which was twice sprayed at tillering and boot leaf stages with 0.1% Hexaconazole. Application of 5% Neem cake extract at tillering and boot leaf stages resulted in 12.66% disease severity with 37.51% reduction in severity and it was at par with the severity recorded due to two application of 1.0% *T. harzianum* where 12.80% diseases severity with 36.82% reduction in severity was recorded and also with the severity recorded due to two application of 0.1% *P. fluorescence* where 13.86% severity with 31.85% reduction in severity were recorded. However, disease severity recorded due to application of Eucalyptus leaf extract, Garlic clove extract and neem leaf extract were at par to each other and also were at par with the effect of bio-agents.

Table 1. Effect of different fungicides, bio-agents and botanicals on percent disease incidence of spot blotch.

Treatment and method of applications	Percent disease incidence			Percent reduction in disease incidence		
	2008-2009	2009-2010	AV.	2008-2009	2009-2010	AV.
T_{1}- Propiconazole	* 12.06 **(20.19)	5.49 (13.43)	8.77	68.35	55.72	62.03
T_{2}- Carbendazim	13.17 (21.24)	4.82 (12.66)	8.99	35.56	61.12	57.78
T_{3}- Hexaconazole	12.52 (20.66)	5.48 (13.52)	9.00	67.14	55.80	61.47
T_{4}-*Trichoderma harzianum*	34.61 (35.86)	9.75 (18.16)	22.18	09.18	21.37	15.27
T_{5}- *Pseudomonas fluorescence*	28.92 (32.31)	9.05 (17.44)	18.98	24.11	27.01	25.56
T_{6}- Eucalyptus leaf extract	27.21 (31.02)	7.96 (16.38)	17.58	28.61	35.80	32.20
T_{7}- Garlic clove extract	35.64 (36.35)	8.94 (17.36)	22.29	64.81	27.90	17.19
T_{8}- Neem leaf extract	29.51 (32.23)	8.22 (16.64)	18.66	22.56	33.70	18.13
T_{9}- Neem cake extract	35.30 (36.25)	8.80 (17.24)	22.05	7.73	29.03	18.38
T_{10}- Control	38.11 (38.09)	12.40 (20.63)	25.25	-	-	--
SE (m)	2.823	0.694				
CD at 5%	8.454	2.078				

*Average of three replications. **Figures given in parenthesis are angular transformed value.

Table 2. Effect of different fungicides, bio-agents and botanicals on percent disease severity of spot blotch.

Treatment and method of applications	Percent disease severity			Percent reduction in disease severity		
	2008-2009	2009-2010	AV.	2008-09	2009-10	AV.
T_{1}- Propiconazole	*27.58 **(31.65)	8.93 (17.37)	18.25	44.42	55.92	50.17
T_{2}- Carbendazim	32.07 (34.47)	7.73 (15.97)	19.90	35.37	61.84	48.60
T_{3}- Hexaconazole	30.32 (33.39)	10.13 (17.95)	20.22	38.90	50.00	44.45
T_{4}- *Trichoderma harzianum*	41.27 (39.94)	12.80 (20.80)	27.03	16.83	36.82	26.82
T_{5}- *Pseudomonasfluorescence*	39.05 (38.65)	13.86 (21.24)	26.43	21.30	31.58	26.44
T_{6}- Eucalyptus leaf extract	40.93 (39.75)	16.43 (24.20)	28.68	17.51	18.90	18.20
T_{7}- Garlic clove extract	35.30 (36.43)	14.13 (21.89)	33.71	28.86	30.25	29.55
T_{8}- Neem leaf extract	38.65 (38.42)	15.41 (23.04)	27.03	22.11	23.93	22.52
T_{9}- Neem cake extract	39.88 (39.14)	12.66 (20.64)	26.27	19.63	37.51	28.57
T_{10}- Control	49.62 (44.76)	20.26 (26.73)	34.94	-		--
SE (m)	0.633	1.533				
CD at 5%	1.896	4.590				

*Average of three replications. **Figures given in parenthesis are angular transformed values.

Table 3. Effect of different fungicides, bio-agents and botanicals on percent yield increase.

Treatment and method of applications	Percent average (q/ha)			Percent yield increase		
	2008-2009	2009-2010	AV.	2008-2009	2009-2010	AV.
T_{1}- Propiconazole	* 51.00	41.67	46.33	56.58	68.90	62.74
T_{2}- Carbendazim	44.17	36.67	40.42	35.61	48.64	42.12
T_{3}- Hexaconazole	42.17	37.83	40.00	29.47	53.34	41.40
T_{4}-*Trichoderma harzianum*	38.17	27.33	32.75	17.19	10.78	13.98
T_{5}-*Pseudomonasfluorescence*	34.50	27.67	31.08	5.92	12.20	9.06
T_{6}- Eucalyptus leaf extract	37.77	31.67	34.72	15.96	28.41	22.18
T_{7}- Garlic clove extract	33.50	27.50	30.50	2.85	11.47	7.16
T_{8}- Neem leaf extract	34.66	29.83	32.25	6.66	20.91	13.78
T_{9}- Neem cake extract	33.73	28.83	31.28	3.56	16.86	20.42
T_{10}- Control	32.57	24.67	28.62	--	--	--
SE (m)	3.110	2.676	----	----		
CD at 5%	9.311	8.012				

*Average of three replications.

During both the crop seasons, that is, 2008-2009 and 2009-2010; it was observed that minimum disease severity was recorded in the crop which was twice sprayed with 0.1% Propiconazole followed by twice application of Carbendazim at tillering and boot leaf stages of crop followed by Hexaconazole. After these two treatments, next minimum disease severity was recorded when crop was sprayed with a bio-agents and botanical, that is, *P. fluorescence* and Neem cake at tillering and boot leaf stages. When we compared among fungicides, bio-agents and botanicals on the basis of disease severity; the lower disease severity was recorded with fungicidal spray.

Effect on yield

During Rabi crop season 2008-2009 highest yield (51.00 q/ha) with yield increase 56.58% was obtained where Propiconazole was applied at tillering and boot leaf stages. It was significantly higher than the yield obtained in the remaining other treatments. Second highest yield, that is, 44.17 q/ha with 35.61% yield increase was obtained where Carbendazim was applied and it was significantly higher than the yield obtained due to application of *T. harzianum* (38.17 q/ha) followed due to application of eucalyptus leaf extract, there was 37.77 q/ha yield and 15.96% yield increase was obtained, which was at par with the yield recorded due to T_5, T_7, T_8 and T_9, respectively.

During Rabi crop season 2009-2010 highest yield 41.67 q/ha with yield increase 68.90% was obtained when Propiconazole was applied followed by Hexaconazole, that is, 37.83 q/ha yield and 53.34% increase in yield. In case of botanicals eucalyptus leaf extract when applied at tillering and boot leaf stages resulted in a yield of (31.67 q/ha and 28.41% yield increase) followed by bio-agents *P. fluorescence* with 27.67 q/ha yield and 12.20% yield increase was obtained.

As per average of both seasons, it was observed that the highest yield was obtained in crop where Propiconazole was applied twice at tillering and boot leaf stages followed by yield obtained in crop where Carbendazim was applied twice, that is, at tillering and boot leaf stages. Overall best result during the year 2008-2009 and 2009-2010 was in Propiconazole where Propiconazole was applied and the average yield obtained was 46.33 q/ha (Table 3).

DISCUSSION

The present study showed that foliar application of fungicides, bio-agent and botanicals can be effective in reducing the severity of spot blotch in wheat. The causal pathogen of spot blotch is a necrotroph and possibly the reduced severity that was observed can be attributed to the nutrients increasing plant cell resistance to infection. Result indicated that two applications of Propiconazole at tillering and boot leaf stages which is already in practice for management of spot blotch disease, gave the maximum reduction in incidence and severity. Propiconazole was found superior at 0.1% concentration in suppressing the spot blotch disease of wheat than any other chemical, bio-agent and botanicals tested. Kalappanavar and Patil (1998) reported that propiconazole, tridimefon and Hexaconazole were the most effective fungicides for management of leaf rust of wheat. Agrawat et al. (1980) found that Carbendazim and Benlate were highly effective against A. helianthi on sunflower. Rao (2006) reported Bayleton as effective fungicide against leaf blight of sunflower which increased yield up to 63%.

Mesta et al. (2003) reported Propiconazole (0.1%) was effective fungicide against Alternaria blight of sunflower. Higher efficacy of Carbendazim and Propiconazole may be due to same dose of Carbendazim and Propiconazole present in crop system for longer time as it was applied for two times. When two applications of Carbendazim and Propiconazole at tillering and boot leaf stages were compared, the Carbendazim seem to be more effective and economic as well. Comparatively higher reduction in incidence and severity of spot blotch was observed due to T. harzianum which was significantly higher than P. fluorescence. Hamdy et al. (2001), reported that under field conditions guard (T. harzianum) reduce 64.29% disease in case of spot blotch of wheat. The P. fluorescence was evaluated under field conditions. Two sprays were applied at tillering and boot leaf stages of wheat and experimental results showed that P. fluorescence minimized the incidence and severity of spot blotch of wheat. Singh et al. (2009) reported that either twice application of Carbendazim, or four application of T. harzianum and P. fluorescence (1:1 ratio) at seed, seedling, tillering and symptoms initiation stage or two application of antagonists at seedling and symptoms initiation stage were almost equally effective in reducing the disease severity of sheath blight in rice. Vidhyasekaran et al. (1997) developed the powder formulation of P. fluorescence and applied in the form of seed treatment and foliar spray.

Shafique et al. (2007) studied effect of aqueous leaf extract of 8 allelopathic tree species including Eucalyptus citridora on germination and seed borne mycoflora of wheat (T. aestivum), they found that aqueous extract of all allelopathic tree species including E. citridora significantly reduced the frequency of occurrence of two most frequent seed borne fungi viz A. alternata and F. solani. Through this finding, it is clear that Eucalyptus leaf, certainly posses some fungicidal activities and due to this reason, application of aqueous extract as foliar spray might have resulted in reducing disease severity of spot blotch caused by B. sorokiniana. Foliar application of aqueous extract garlic clove to the wheat plants, at tillering and boot leaf stages also reduced the spot blotch incidence and severity. Through the findings of Hason et al. (2005), antifungal activity of Allium sativa (Garlic) against B. sorokiniana in wheat is well proven; during present investigation foliar application of aqueous garlic clove extract resulted in reduction of spot blotch severity which is well in accordance with the findings of earlier workers. Aqueous extract of Azadirachta indica (Neem) has been reported to cause significant growth inhibition of certain fungi such as Rhizoctonia solani, Botrytis cinera and Fusarium oxysporum (Alkhail, 2005).

During present investigation, aqueous extract of Neem leaf at 5% was applied as foliar spray at tillering and boot leaf stages, which showed reduction of disease severity. Twice application of Neem cake aqueous extract at 5% to the wheat plants, at tillering and boot leaf stages resulted in reduction of disease severity and incidence. Mohammad and Aman (2001) reported that A. indica controlled 56.96% leaf rust of wheat. Sajid et al. (1995) studied the comparative effects of Neem products and baytan against leaf rust of wheat in the laboratory. Neem oil and Baytan (Triadimenol) completely inhibited germination of P. recondita f.sp. tritici uredospores. In the field, Neem oil at 4% concentration checked leaf rust on wheat after four applications but Baytan at 0.1% showed excellent rust control and best improvement in yield. These reports showed that application of Neem based products as foliar spray reduced the foliar diseases which also support the present findings.

Conclusion

For efficient management of B. sorokiniana causing spot blotch of wheat, use of efficient strains of biological controlling agents botanicals and fungicides needs to be sincerely incorporated in the cultivation package of important crops. The findings from this study suggest that foliar application of fungicides, bio-agents and botanicals can be used to reduce the severity of spot blotch on wheat. Present investigation concluded that the fungicides (Propiconazole, Carbendazim and Hexaconazole) bio-agents (T. harzianum and P. fluoresce) and botanicals (Eucalyptus leaf extract, Garlic clove extract, Neem leaf extract and Neem cake extract) in two season experiments were found to be effective in reducing the disease incidence, severity and increasing grain yield in wheat.

Conflict of Interest

The authors have not declared any conflict of interest.

ACKNOWLEDGEMENT

Authors are thankful to the Department of Plant

Pathology and University authority for providing facilities to conduct the experiment. Sources of literatures are also dully acknowledged.

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academicJournals

Vol. 10(25), pp. 2501-2505, 18 June, 2015
DOI: 10.5897/AJAR2014.8686
Article Number: E5057BB53510
ISSN 1991-637X

http://www.academicjournals.org/AJAR

African Journal of Agricultural Research

Review

Synergistic effect of methane emission through ruminant production

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Received 14 March, 2014; Accepted 19 May, 2015

The world we live in is not in isolation, therefore every action undertaken by humans and animals have a direct effect on humans. Some sort of boomerang effect. Methane is produced mostly by anaerobic microbial metabolism in the rumen and sent out through eructation into the environment. Methane and other gases such as carbon dioxide and nitrous oxide (CO_2 and N_2O) have been giving great concern worldwide as they represent greenhouse gases (GHG). Though produced as a result of the actions of methanogens (bacteria) within the rumen, methane gas portend grave consequences through global warming and other negative effects as it relates to interaction between the environment and living things. Hence, this paper discusses the effects of methane, the producers and action of production and mitigation strategies are all reviewed in this study.

Key words: Methanogens, rumen, livestock production, environment, mitigation strategies.

INTRODUCTION

Livestock producers are confronted with a lot of challenges culminating into pressure through public interactions or complaints about maintaining a healthy, balance atmosphere and adoption of welfare friendly environments Aluwong et al. (2011). Similarly, Steinfield et al. (2006) identified ruminants as a major contributor to greenhouse gases. It is a well-known fact that livestock especially ruminants play a leading role in methane emissions. Enteric fermentation and manure production represents about 80% of agricultural methane emissions and about 35 to 40% of the total anthropogenic methane emissions (Gerber et al., 2007). Furthermore, Hegarty et al. (2010) reported that the release of methane from livestock production is produced by anaerobic microbial metabolism in the digestive tract and in manure, also, the release of nitrous oxide from agricultural soils are both greenhouse gases (GHG).

Cole et al. (1997) reported that methane production through enteric fermentation is of great concern worldwide due to its contribution to the accumulation of greenhouse gases (GHG), mainly carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) in the atmosphere. This contribution has increased the temperature of the earth surface. Wang and Chen (2009) opined that accumulation of these greenhouse gases are known to be increasing at the rate of 0.3 to 0.9% per annum due to natural (wetland, termites, oceans and fresh water, e.t.c.) and anthropogenic effects (that is, landfills, ruminants, wasteland, energy, biomass burning, e.t.c.) on the carbon and nitrogen cycles.

Ruminants have been widely reported to be one of the major contributors to these GHG and almost 50 to 80%

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of all the methane emission comes from the agricultural sector especially ruminants (NRC, 2002; Steinfield et al., 2006). Ruminant animals with low levels of production efficiency have relatively high methane emissions per unit of product. This situation results because these animals use a large fraction of their feed intake solely for maintenance (that is, for the basic metabolic processes required to stay alive). Methane emissions associated with this "maintenance" feed intake are spread over a relatively small level of production, resulting in a high level of emissions per unit product. In animals with higher levels of production efficiency, the "maintenance emissions" are spread out over a larger amount of production, thereby reducing methane emissions per unit product (although emissions per individual animal may be higher).

UNFCCC (2007) and Aluwong et al. (2011) reported that methane has a radioactive effect on the climate; its potential on global warming for over a decade is 21 times above that of CO_2 while CO_2 has a serious effect on ozone formation. Forster et al. (2007) and Hook et al. (2010) reported that methane is a potent trace gas due to its effect on global warming. It is the second largest anthropogenic greenhouse gas, behind CO_2, it is estimated to have a total concentration of 1774 ± 1.8 parts per billion (ppb). Methane is a colourless and odourless gas. Its production in the rumen occurs as a by-product of microbial (anaerobic) fermentation of feed through the presence of a group of microorganisms referred to as methane producing bacteria known as methanogens. Methanogens reside in gastrointestinal tract of ruminants. These organisms play an important role in converting organic matter to methane (that is, use the hydrogen and carbon dioxide produced as end products of microbial digestion to generate energy for growth producing CH_4 as an end product). Kimberly et al. (2004) reported that the microbial activity (bacteria, protozoa and fungi) in rumen hydrolyses, the dietary organic matter to amino acid and sugars and these will now be fermented anaerobically to volatile fatty acids (VFAs), hydrogen; CO_2 and other end products. Methanogens then reduces carbon dioxide to methane, preventing the accumulation of hydrogen. When hydrogen ions accumulate in the rumen environment, it results in the decline of pH, and subsequent inhibition of many organisms that are essential for fibre digestion.

$$CO_2 + 4H_2 \longrightarrow CH_4 + 2H_2O$$

In this reaction, CO_2 combines with H_2 to produce CH_4. The methane from ruminants is produced by methanogens. These microbes are responsible for between 0.25 to 0.37% of the total methane produced O'Mara (2004). Methanogens work at their optimal level in anaerobic conditions and most of the microbes in the rumen are anaerobes. Factors such as the type of carbohydrate in the diet, level of feed intake, digester passage rate, presence of ionophores, lipids in the diet and ambient temperature influence the emission of methane from ruminants (McAllister et al., 1996).

In order to decrease the methane production, these vital factors must be taken into consideration: Acetate and butyrate are the principal fermentation products of protozoa. Removal of protozoa population will cause shift in fermentation of the substrate from acetate and butyrate to propionate and decrease the formation of methane (McAllister et al., 1996).

Bell and Eckard (2012) summarised the process of methanogenesis thus:

1. Glucose equivalents from plant polymers or starch are hydrolysed by extracellular microbial enzymes to form pyruvate in the presence of protozoa and fungi in the digestive tract:

$$\text{Glucose} \longrightarrow 2\ \text{Pyruvate} + 4H$$

(Embden-Meyerhof-Parnas pathway);

2. According to Moss et al. (2000), the fermentation of Pyruvate involves oxidation reactions under anaerobic conditions producing reduced co-factors such as NADH. Reduced co-factors such as NADH are then re-oxidised to NAD to complete the synthesis of volatile fatty acids (VFAs) with the main products being acetate, butyrate and propionate:

2H producing reactions:

$$\text{Pyruvate} + H_2O \longrightarrow \text{acetate (C2)} + CO_2 + 2H$$

2H using reactions:

$$\text{Pyruvate} + 4H \longrightarrow \text{Propionate (C3)} + H2O$$

$$2C_2 + 4H \longrightarrow \text{butyrate (C4)} + 2H_2O$$

$$CO_2 + 8H \longrightarrow \text{methane } (CH_4) + 2H_2O$$

3. The VFAs are then available for absorption through the digestive mucosa into the animal's blood stream. The production of acetate and butyrate provides a net source of hydrogen available for utilization by propionate. Thereafter, methanogens eliminate the available hydrogen by combining with carbon dioxide (CO_2) to produce methane:

$$4H_2 + CO_2 \longrightarrow CH_4 + 2H_2O$$

The molar percentage of the different volatile fatty acids produced during fermentation influences the production of methane in the rumen. Acetate and butyrate promote methane production while propionate formation can be considered as a competitive pathway for hydrogen use in the rumen.

Bell and Eckard (2012) reported an inverse relationship between the production of methane in the rumen and the presence of propionate. If the ratio of acetate to propionate was greater than 0.5, then hydrogen would become available to form methane. If the hydrogen produced is not correctly used by methanogens, such as when large amounts of fermentable carbohydrate are fed, ethanol or lactate can form, which inhibits microbial growth, forage digestion and any further production of VFAs. In practice, ethanol or lactate may form, but any excess hydrogen is simply eructated.

Zhou et al. (2011) reported that rumen methanogenesis result in the loss of 6 to 10% of gross energy intake or 8 to 14% of the digestible energy intake of ruminants. This losses varies based on the species, geographical location, feed quality, feed intake, feed composition and processing of the feed (Okine et al., 2004; Cottle et al., 2011).

Methanogens are unique and a distinct group of microorganisms. They are nutritionally fastidious anaerobes that grows in an environment with a redox potential and at neutral pH between 6 and 8 while some grow under extreme pH 3 to 9.2 (Jones et al., 1987; Stewart and Bryant, 1988). Methanogens belongs to group Archea and phylum Euryarchaeota and unlike bacteria; they lack peptidoglycan in their cell wall which is replaced by pseudomurein, heteropolysaccharide and protein. They possess three co - enzymes which have not been found in other microorganism. Methanogens use the process of formation of CH_4 to generate energy for growth and the substrate used in the process include H_2, CO_2, formate, acetate, methanol, methylamines, dimethyl sulfide and some alcohol (Boadi et al., 2004).

In ruminants, 87 to 93% of methane production occurs in the foregut, with the highest rate of production coming after eating. In sheep, almost 90% of the methane produced in the hindgut has been found to be absorbed and expired through the lungs, with the remainder being excreted through the rectum (Murray et al., 1976). Rectum enteric methane losses have been estimated to be 7% by Grainge et al. (2007) and 8% by Tamminga et al. (2007) of methane output in dairy cows compared to 1% found in sheep (Murray et al., 1976).

If the quantity of methane produced by the livestock can be decreased, it may also decrease carbon footprint; consequently, it may increase the efficiency of feed utilization and decrease production costs. One area of decreasing ruminal methane production is to increase the production of volatile fatty acid, that is, increasing the propionate proportion by the ruminal microbial population. Propionate is used more efficiently by ruminants than other volatile fatty acids, increase in propionate production can decrease the quantity of feed required per unit of weight gain. Kobayashi (2010) summarised that methane emitted from ruminants is regarded as a loss of feed energy and a contributor to global warming. Methane is the most prominent sink for hydrogen synthesized in the rumen. Methane contains gross energy therefore, its emission during rumen fermentation is considered to be a loss of energy equivalent to 2 to 12% of the gross energy of animal feed Kobayashi (2010).

Another negative aspect of methane emission from ruminants is the possible contribution to global warming. Annual methane production from cattle accounts for 15 to 20% of global methane production. This level of production corresponds to 3 to 5% of global CO_2 production when converted to CO_2 based on the global warming effect of methane (IPCC, 2001).

The main health hazard associated with methane is that it is highly combustible. Mixtures of 5 to 15% methane in air can be explosive. Also, large concentrations of methane in enclosed areas can lead to suffocation; as large amounts of methane will decrease the amount of available oxygen in the air. The effects of oxygen deficiency are nausea, headaches, dizziness and unconsciousness. Utility companies that use natural gas add a small amount of smelly, sulfur-containing compounds so that gas leaks can be detected before methane concentrations are large enough to cause suffocation or explosions.

By far the most important non - CO_2 greenhouse gas is methane, and the number one source of methane worldwide is animal agriculture. It is responsible for nearly as much global warming as all other non-CO_2 greenhouse gases put together. Methane is 21 times more powerful as greenhouse gas than CO_2. While atmospheric concentrations of CO_2 have risen by about 31% since pre-industrial times, methane concentrations have more than doubled. Whereas human sources of CO_2 amount to just 3% of natural emissions, human sources produce one and a half times as much methane as all natural sources. In fact, the effect of methane emissions may be compounded as methane-induced warming in turn stimulates microbial decay of organic matter in wetlands.

With methane emissions causing nearly half of the planet's human-induced warming, methane reduction must be a priority. Methane is produced by a number of sources, including coal mining and landfills; however, the number one source worldwide is animal agriculture.

Mitigation strategies

Many reviews are available and many researches are still ongoing on how to mitigate methane emission especially in ruminant production area (Moss et al., 2000; Boadi et al., 2004; O'Mara, 2004; Aluwong et al., 2011) with respect to nutrition and influence on the rumen microbes in the rumen. To provide solution to this issue and hitherto to nutrition, successful mitigation practices must account for the rumen micro biota / a proper understanding of the rumen ecology must be well grasped (Martin et al., 2010). Zhou et al. (2011) reported that various methane mitigation methods have been applied (McAllister et al., 1996; Martin et al., 2010), such as defaunation (Ushida et al., 1997), dietary inclusion of monensin (Van Nevel and Demeyer, 1977), redirection of reducing equivalents to alternate acceptors (Johnson and Johnson, 1995) and stimulation of methanogens competitors such as acetogens (Leedle and Greening, 1988). However from their conclusion, it was observed that many of these approaches were not authenticated through microbial adaptation shortly after the application of all these methods, and to this regard long-term effect of methane mitigation methods needs to be sourced.

Conclusion

However, the following mitigation strategies are to be considered: The feeding of highly digestible forages for grazing and confined cattle, inclusion of legumes in forage mixtures, supplemental fats in diets and dietary additives that manipulate rumen function and On-farm practices.

On farm practices include: Improvements in efficiency through application of best practice in ‘on-farm’ management, the application of animal genetics and improved feed quality (that is, Genetic selection for production traits, feed testing and ration balancing, pregnancy testing will reduce enteric CH_4 emissions by reducing feed costs associated with animal maintenance).

In a bid to mitigate against methane emission, use of probiotics should be explored for their mitigation potentials. Biotechnological solutions based on the introduction of new or modified microorganisms to the animals, immunological and hormonal control of gut function, or the use of genetically modified crops and/or animals.

Areas that require long term research support include: The potential for selection of low methane emitting animals and the development of products to inhibit methanogenesis, provide alternate electron acceptors, or reduce rumen protozoa populations.

Conflict of Interest

The author(s) have not declared any conflict of interest.

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Vol. 10(25), pp. 2506-2515, 18 June, 2015
DOI: 10.5897/AJAR2014.9077
Article Number: BB08E3353513
ISSN 1991-637X

http://www.academicjournals.org/AJAR

African Journal of Agricultural Research

Full Length Research Paper

Agro-climatic zoning for citriculture in the Agreste region of Pernambuco State, Brazil

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Received 14 August, 2014; Accepted 26 April, 2015

The objective of this study was to accomplish an agro-climatic zoning for the Agreste region of Pernambuco State, Brazil, with the aim to identify agro-climatic zones for citrus cultivation. Monthly climatic data of 100 stations from over 20-year observation series (1911 to 1990) were selected within and close to the study area. From climatic data of mean air temperature and rainfall, we calculated the climatic water balances using available water capacity (AWC) of 50 and 100 mm. From data of both potential and estimated actual evapotranspiration, agro-climatic zones were established in agreement with the Water Requirement Satisfaction Index (WRSI). According to our study, the annual temperature variation in the Agreste mesoregion of Pernambuco State, with minimum temperature of 16.4°C and maximum of 33.4°C, is not a limiting factor for citrus production. Fifty municipalities in the region are located in the favorable agro-climatic zone for citrus cultivation, what represents an area of 12,000 km^2 yet to be explored since less than 0.5% of it is being cultivated. Other 16 municipalities are located in the intermediate zone, with moderate risk, while five of them are in the adverse zone, presenting high climatic risk and water deficit.

Key words: Citrus production, temperature, water balance, orange, tropical region.

INTRODUCTION

Facing the uncertainty that shapes future climatic changes on the planet productive system, it is essential to identify agro-climatic boundaries according to crop requirements, decentralizing production and improving agricultural planning. The agro-climatic zoning aims decision making of producers and increases chances of success on the use of the property natural resources (Assad, 2001).

Citrus plants, of Asian origin, were introduced to Brazil, probably in Bahia State, during the first colonizing expeditions (Lopes et al., 2011). The *Citrus* genus are composed of medium-sized plants that produce white fragrant flowers and hesperidium-type fruits containing vesicles filled by a fluid of great commercial interest (Araújo and Roque, 2005). The world main cultivated species are *Citrus sinensis* (L.) Osbeck, the sweet oranges; *C. latifolia* Tanaka ex Q. Jiménez, the limes; and *C. reticulata* Blanco, the mandarins (Pompeu Junior,

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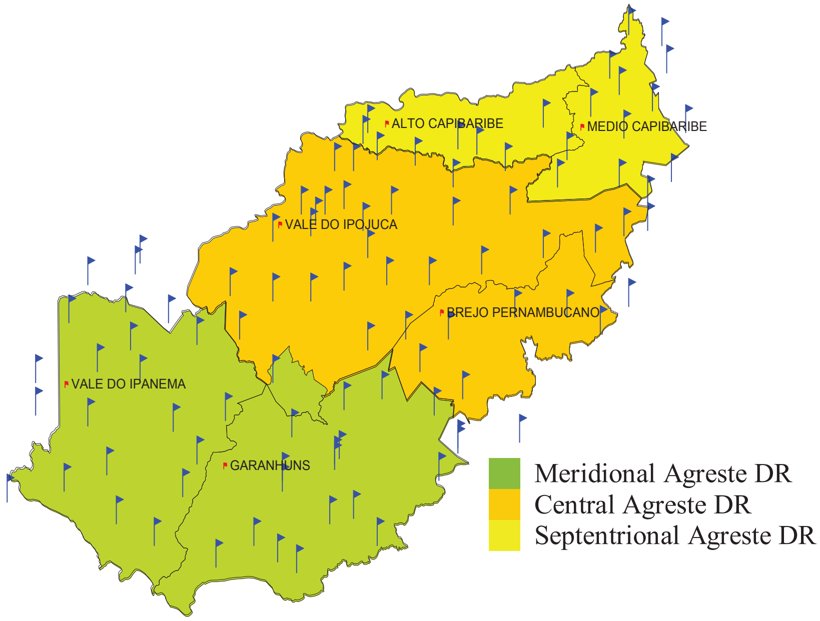

Figure 1. Agreste mesoregion of Pernambuco State, Brazil, with Development Regions (DR) and respective microregions, and pluviometric stations from which data were collected for this study.

2001). From all of the citrus fruits produced and traded in Brazil, sweet oranges comprise 90.3%, limes and lemons, 5.1%, and mandarins, 4.6% (IBGE, 2013).

The citrus cultivated area, in Brazil, consists of around 782,000 ha, with a mean of 833 trees ha^{-1}; production in 2012 was about 19,298,835 tons (FAO, 2014). In 2005, Pernambuco State was classified as the 13th greatest citrus producer in the country, achieving the main yield of 38.51 t ha^{-1} of sweet oranges, limes, and mandarins (IBGE, 2005). From 1962 to 2009, the Brazilian citriculture sector exported, according to 2009 values, nearly US$60 billion, resulting in a mean of US$1.3 billion per year (Neves et al., 2014).

The Garanhuns region in Pernambuco State presents expansion potential for cultivation of dessert citrus due to its altitude (Passos et al., 2005). According to Erickson (1968), the lowest base temperature for citrus growth is 12.8°C; growth is paralyzed below it. When superior to 37°C, there is no growth, so the ideal temperature ranges from 21 to 32°C. Furthermore, the development of citrus plants is very influenced by climatic indices related to temperature, which define the plant cycle according to degree days (Wrege et al., 2004).

Considering different citrus cultivation regions in the world, the annual rainfall is seasonal and varies from 1,000 to 2,000 mm, normally presenting a dry season with evapotranspiration extremes ranging from 600 to 1,300 mm per year (Ortolani et al., 1991). In this sense, the water balance is an important tool in agro-climatic zoning, as it allows monitoring of water quality in the soil as well as understanding of its relationship with crop development and growth (Pereira et al., 2002).

The Brazilian citrus agribusiness is highly competitive in the international market. Some factors contribute to this situation, such as action of important research institutions, low production costs, appropriate climate, proximity of the productive sector that favors production flow, and good product insertion in the international market.

By not having robust studies for the expansion and adaptation of culture in the Brazilian Agreste a thorough study is needed to distinguish and increase the planting areas, contributing to the increase in production. Therefore, the objective of this study was to accomplish an agro-climatic zoning for the Agreste region of Pernambuco State, Brazil, defining agro-climatic zones for citrus cultivation.

MATERIALS AND METHODS

The Agreste mesoregion of Pernambuco State, Brazil, is located between the latitudes 7°30' and 9°23' S, and longitudes 35°18' and 37°32' W, with an area of 24,387 km^2 and means of 820 m altitude, 22.5°C annual temperature, and 782.4 mm annual rainfall. It is divided into three Development Regions (DR): Meridional Agreste with 26 municipalities; Central Agreste with 26 municipalities; and Septentrional Agreste with 19 municipalities. Each DR is also divided into two microregions (Figure 1).

Agreste is an intermediate region between areas of wet and dry climate (Forest Zone and Sertão/Backwoods, respectively), presenting similar climates at the borders. The Intertropical Convergence Zone (ITCZ) is more effective near Sertão/Backwoods, and March is the wettest month. Regarding the border with the Forest Zone, the Eastern Systems are more

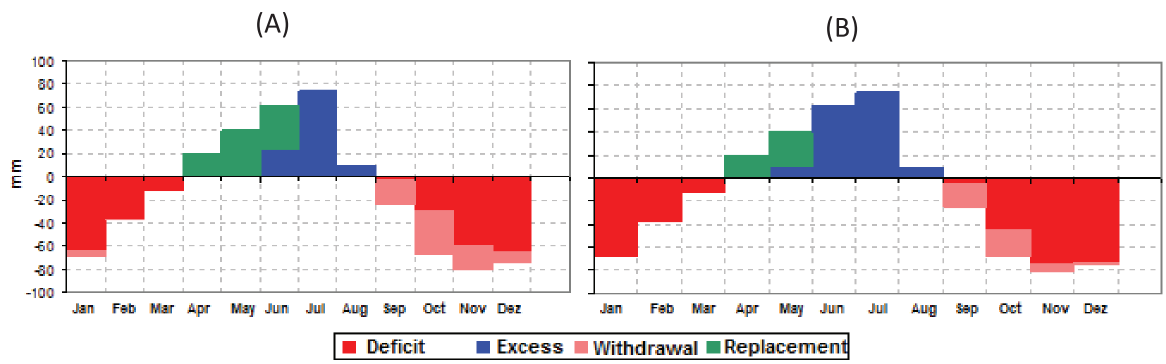

Figure 2. Normal Water Balance for Garanhuns microregion for Available Water Capacity (AWC) of 100 mm (A) and 50 mm (B).

important than ITCZ, and June is the wettest month (Araújo Filho et al., 2000).

Data of monthly mean rainfall of 100 selected stations were used (Figure 1) with the aim to establish a satisfactory period of climatic observations and better spatial distribution with data series from more than 20 years of records (1911 to 1990) distributed in and around the study area and borders with Sertão/Backwoods and Forest Zone. To estimate the mean air temperature according to the geographical coordinates (latitude, longitude, and altitude) of the stations that had only rainfall records, we used the software Estima T version 2.0 (Cavalcanti et al., 2006), which groups, by area, states of Northeast Region with coefficients of quadratic regression for estimates of monthly mean, maximum, and minimum temperatures as established by Cavalcanti and Silva (1994).

The potential evapotranspiration (ETP) was estimated according to the method described by Thornthwaite (1948). The climatic water balance for available water capacity (AWC) of 50 and 100 mm was calculated using BHnorm 6.1 software from an EXCEL™ spreadsheet elaborated by Rolim et al. (1998), who used the method described by Thornthwaite and Mather (1955) adjusted according to criteria reported by Mendonça (1958). As a result, the water balance provided estimates of actual evapotranspiration (ET), water deficit (DEF), water excess (EXC), and soil water storage (STO) for each month.

The map of the Agreste region of Pernambuco State was used to prepare the maps Agro-climatic. After the Climatic Water Balance was calculated, the obtained values were inserted in EXCEL™ spreadsheets. Contour maps (isolines) were generated by the software SURFER® version 8.0 (2002). Kriging was the applied estimate method.

Among the commonly used estimate methods, the Kriging geostatistical may be considered the best linear estimator without bias, which aim is to minimize estimate variance (Landim et al., 2002). The parameters used to define Agreste agro-climatic suitability were based on monthly means of rainfall and temperature.

The water balance results from normal rainfall and temperature data were used to elaborate maps of total annual potential and actual evapotranspiration, water deficit, and water excess. To visualize those Agreste agro-climatic zones indicated for citriculture, maps with results of the Water Requirement Satisfaction Index (WRSI) were developed.

RESULTS AND DISCUSSION

The results, as a histogram of the water balance extract for Garanhuns micro-region, enables observation of DEF, EXC, and areas of soil water withdrawal (negative alteration, ALT-) and soil water replacement (positive alteration, ALT+) (Figure 2A and B). We observed that the rainy season starts in April; June is the wettest month. The same occurs in Médio Capibaribe and Brejo Pernambucano, however with a shorter period. For all micro-regions, the lowest soil moisture percentage is concentrated in October and November, what corroborates with Rossato et al. (2004).

The Brazilian Agreste region of Pernambuco State presents spatial and seasonal variation of the total annual rainfall among the Development Regions Meridional, Central, and Septentrional Agreste; the latter shows minor spatial variation for lower values than 800 mm per year. Within each DR, there is variation from east to west, which extremes present the highest total annual rainfall that exceeds 900 mm. According to Araújo Filho et al. (2000), this is a characteristic of border regions, which are influenced by specific meteorological systems, such as Intertropical Convergence Zone (ITCZ) at the western border, and Eastern Systems alongside the Forest Zone (Figure 3).

The rainfall regime in Agreste is favorable for citrus cultivation in all microregions. However, the microregions Garanhuns, Brejo Pernambucano, and Médio Capibaribe, that border the Forest Zone, are more favorable for several varieties according to their water requirements, as those microregions present total annual rainfall between 1,000 and 2,000 mm, with rainy season between April and August. According to the 900 mm isoline highlighted on the map, we could identify the regions with minimum annual rainfall limit cited in the literature for most citrus.

Restrictions on the need to take measures to mitigate effects of moisture deficit during the dry season include: larger plant spacing; appropriate rootstocks; cultural practices to minimize drought effects, such as supplemental irrigation; and pruning to reduce foliage volume and soil water consumption.

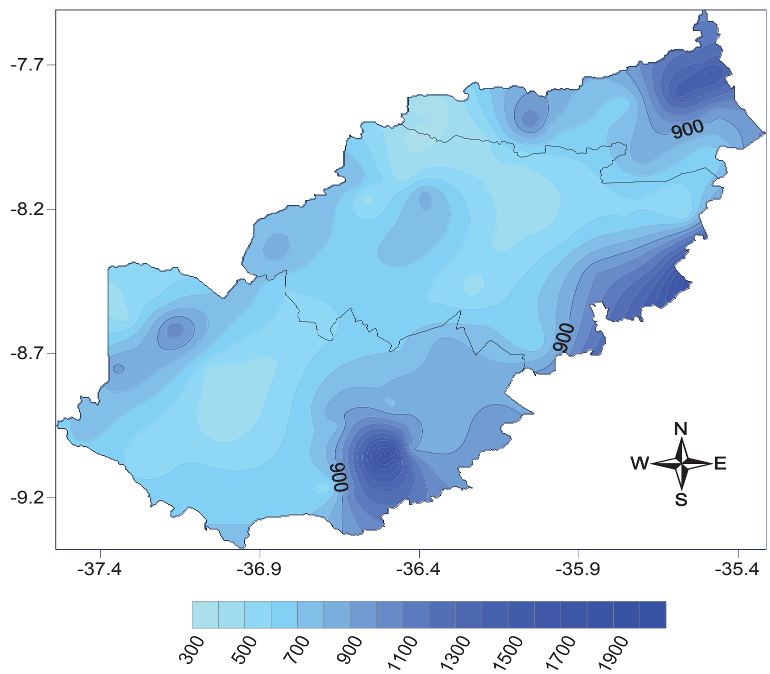

Figure 3. Map of total annual rainfall (mm) in the Agreste region of Pernambuco State, Brazil.

According to Cruz et al. (2003), although citriculture is socioeconomically important in Brazil Northeast, yield in that region is considered low due, mainly, to water deficit that occurs over more than six months per year, corresponding, in general, to high temperatures. In this sense, an alternative management is necessary to increase citrus cultivation under conditions of water deficiency, reducing effects of the atmospheric demand on plants and soil. Therefore, the need to improve collection and storage of rainwater is evident, so that cultivation during the dry season is secured.

The Agreste region of Pernambuco State presents mean minimum temperatures ranging from 16.4 to 20.9°C, and mean maximum from 24.0 to 33.4°C; the lowest temperatures vary from central Meridional Agreste to western Central Agreste, besides a small area located northwest of Septentrional Agreste. There is lower spatial variability for minimum temperatures ranging from 16.4 to 19.9°C; for maximum temperatures varying from 24.0 to 29.5°C, the opposite occurs. That is why citrus orchards in the region present variation on the phenological stage. In regions characterized as high swamps, the relief acts as temperature attenuator, since the air temperature decreases according to the altitude at a rate of 0.6°C each 100 m, what corroborates with Pereira et al. (2002), who described the adiabatic process physical principle for humid air (-0.6°C/100 m).

From the compound map of altitude and temperature, we verified that the annual mean temperature varies from 19.9 to 24.9°C (Figure 4). There is an increased thermal fluctuation according to the altimetric variation.

Altitude in Agreste varies between 100 and 1,050 m (Figure 4). Bluish areas indicate altitudes ranging from 700 to 1,050 m, and annual mean temperatures, from 19.9 to 22.9°C. High swamps are found in these regions, presenting characteristic and favorable microclimates for farming. Passos et al. (2005) reported that mandarin species and hybrids do respond to perspectives of cultivation at high altitudes, once some farmers in Bahia State cultivated the Ponkan variety under such conditions, and obtained superior quality, regarding fruit color and weight, to those produced in other regions.

The annual Potential Evapotranspiration (ETP) corresponds to the sum of monthly estimates obtained by the model described by Thornthwaite (1948), which shows the water that is, in theory, lost to the atmosphere. The Agreste region presents ETP varying between 880 to 1,400 mm per year. Spatialization of ETP values lower than 1,000 mm comprises northern Meridional Agreste to central and western Central Agreste, plus a small area located northwest of Septentrional Agreste (Figure 5).

The Actual Evapotranspiration (ET) indicates, quantitatively, the water evapotranspirated along a determined period of time, since it is limited by rainfall during that same period. Considering AWC of 100 mm, variation of the total annual ET in Agreste varies between 350 and 1,150 mm. There is greater spatial variability for ET values superior to 700 mm in central and western Meridional Agreste, and from the central area of Central

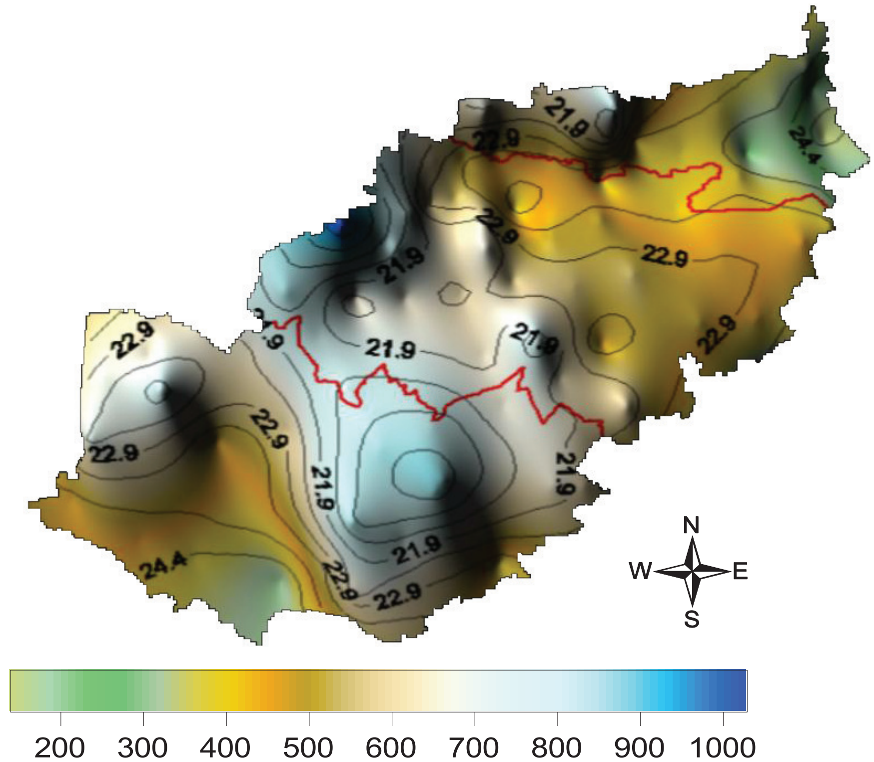

Figure 4. Compound map of annual mean temperature (°C) and Altitude (m) in the Agreste region of Pernambuco State, Brazil.

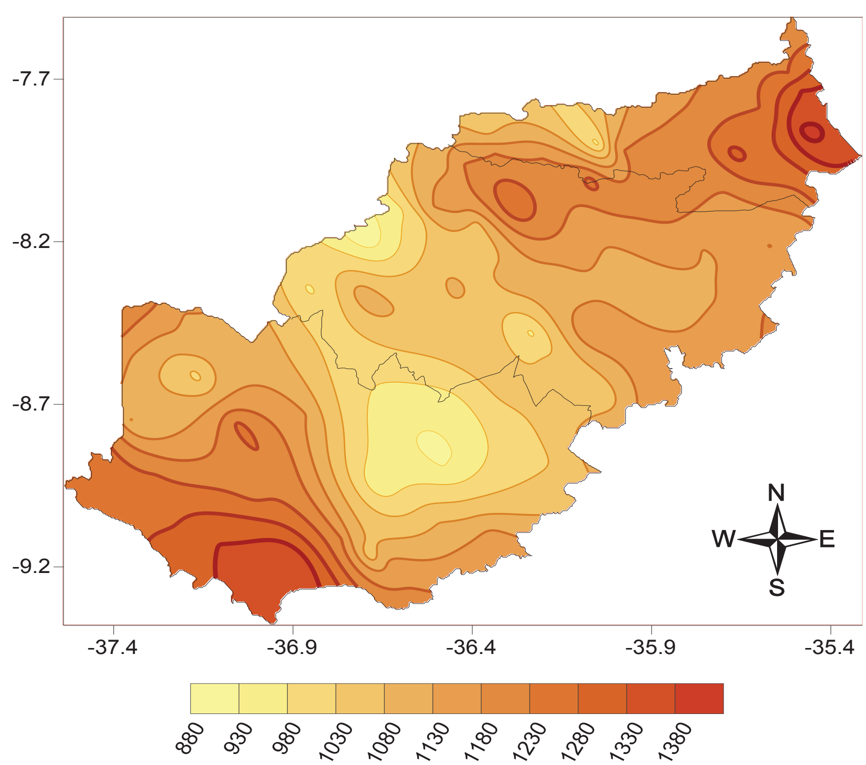

Figure 5. Map of accumulated potential evapotranspiration (mm) in the Agreste region of Pernambuco State, Brazil.

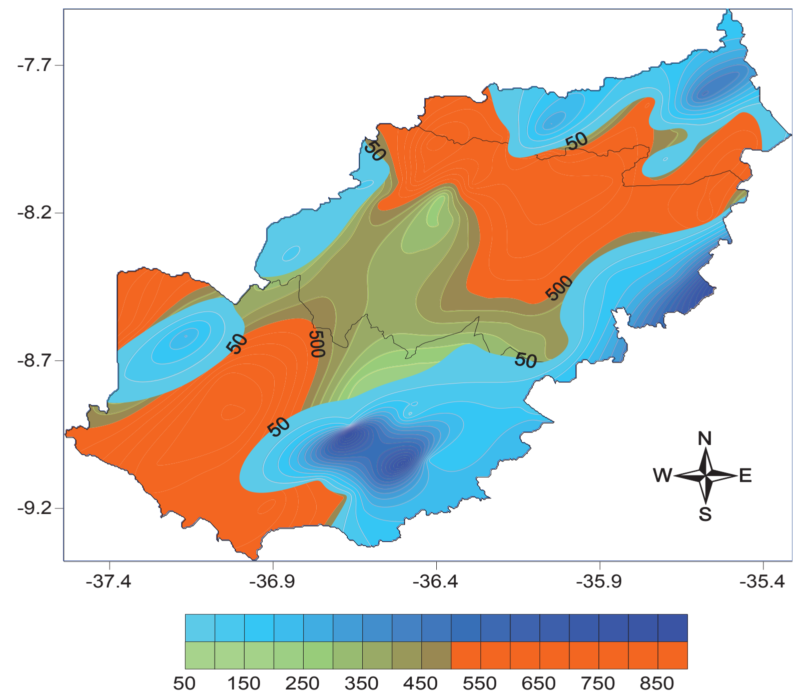

Figure 6. Map of limit zones of water excess (mm) regarding water deficit for Available Water Capacity of 100 mm, for the Agreste region of Pernambuco State, Brazil.

Agreste to western Septentrional Agreste. However, for AWC of 50 mm, these same areas present lower spatial variability, as rainfall ranges from 300 to 600 mm per year.

Analysis of accumulated Water Deficit (DEF) in Agreste, for AWC of 100 and 50 mm, indicated the same deficiency range, that is, from 100 to 900 mm; water deficits lower than 500 mm for both AWCs are better spatialized in and among microregions. Therefore, citriculture may be developed in the Agreste region of Pernambuco State with differentiated and decentralized results. According to Rolim et al. (1998), the effect of water stress on crop growth and yield depends on water deficit intensity and duration, and on crop species or variety. Coletti (2000) highlights that, for citrus, the water deficit may favor flower induction since the stress period is controlled; if extreme, it may damage plants, promoting excessive flower production, what would cause undue fruiting, thus lower fruit quality; moreover, extreme conditions of water stress may delay flowering, resulting in late harvest and respective trading price problems.

Valipour (2014a) verifying the importance of solar radiation, temperature, relative humidity and wind speed in the calculation of reference evapotranspiration shows the importance of these factors for each region evaluated, due to varying weather conditions. Thus the importance of performing agro-climatic zoning for each micro-region that wants to enter or expand a particular culture.

Although Valipour (2014b) indicate that the method of estimating the FAO reference evapotranspiration model Penman Monteith did not obtain greater efficiency in the province of Iran, other research has shown its efficiency (Moeletsi et al., 2012; Sahoo et al., 2012; Valiantzas, 2013) and in Brazil this method has proven quite efficient to calculate the reference evapotranspiration (Junior Borges et al., 2012).

The compound map of DEF and EXC zones (Figure 6) shows blue areas indicating EXC ranging from 50 to 900 mm per year, with larger areas located in northern Médio and Alto Capibaribe, and along the eastern and western borders of Central and Meridional Agreste. Garanhuns microregion is highlighted in Meridional Agreste with greater area and EXC spatial variability. In these locations, rainfall volume is superior to 800 mm per year.

In regions with null water excess, DEF ranges from 50 to 900 mm. Water deficits superior to 500 mm are indicated by the orange color, where altitude varies between 350 and 550 mm. In the area comprising northern Meridional Agreste to the central region of Central Agreste, water deficit ranges from 250 to 500 mm, and altitude, from 650 to 900 mm. Since altitude contributes to decreased mean temperatures, the thermal condition may act as a DEF attenuator; when also considering the orange areas, we observed that rainfall varies from 400 to 500 mm, and DEF, from 500 to 800 mm. On the other hand, the green area indicates rainfall varying between 500 and 700 mm, and DEF, between

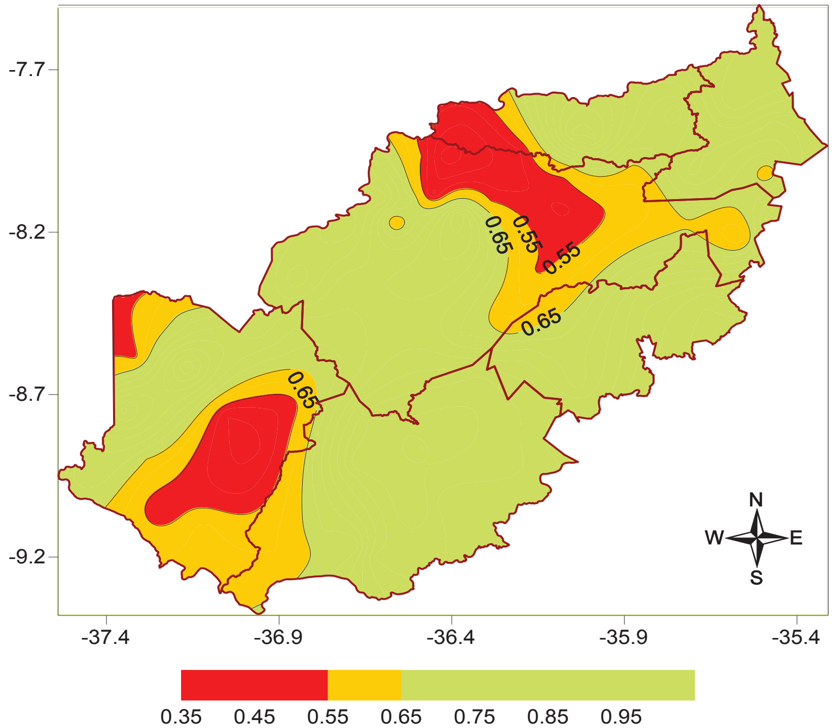

Figure 7. Map of agro-climatic zones in the Agreste region of Pernambuco State, Brazil, defined according to the Water Requirement Satisfaction Index (WRSI) for AWC of 100 mm. WRSI ≥ 0.65 – Favorable agro-climatic zone, with low climatic risk; WRSI ≥ 0.55 and < 0.65 – Intermediate agro-climatic zone, with moderate climatic risk; and WRSI < 0.55 – Adverse agro-climatic zone, with high climatic risk and water deficit.

250 and 500 mm.

The agro-climatic zoning for citrus cultivation in the Agreste region of Pernambuco State (Figure 7) was established according to the Water Requirement Satisfaction Index (WRSI), which indicates the water amount consumed by the plant and desired amount to ensure maximum productivity. The WRSI is defined by the relationship between the actual evapotranspiration and maximum evapotranspiration (ET/ETm). Considering the climatic characteristics of the Agreste region, the following classes of climatic risk were defined:

WRSI ≥ 0.65 – Favorable agro-climatic zone, with low climatic risk;
WRSI ≥ 0.55 and < 0.65 – Intermediate agro-climatic zone, with moderate climatic risk;
WRSI < 0.55 – Adverse agro-climatic zone, with high climatic risk and water deficit.

The maximum evapotranspiration capacity (ETm) was obtained based on the mean crop coefficient (Kc) of 0.8, and it was equivalent to 80% ETP for citrus plants that had been cultivated for more than two years. The applied coefficient resulted from studies by SegHidro, in Campina Grande, Paraíba State, Brazil (EMATER, 2006).

The Agreste region of Pernambuco State comprises 21 municipalities in zones of moderate and high climatic risk, as follows: Altinho, Bezerros, Buíque, Cachoeirinha, Cumaru, Gravatá, Iati, Itaíba, Passira, Pedra, Riacho das Almas, São Caetano, Tacaimbó, Taquaritinga do Norte, Toritama, and Tupanatinga; plus Águas Belas, Brejo da Madre de Deus, Caruaru, Jataúba, and Santa Cruz do Capibaribe, which are those with greater area under high climatic risk. Cachoeirinha, Iati, Jataúba, São Caetano, Tacaimbó, and Toritama municipalities do not have orange or lime production. The others have already been cultivating citrus regardless the climatic limitation.

Among those municipalities located in the favorable agro-climatic zone, with low climatic risk, Angelim, Barra de Guabiraba, Belo Jardim, Bom Conselho, Bom Jardim, Bonito, Brejão, Camocim de São Félix, Correntes, Feira Nova, Garanhuns, João Alfredo, Lajedo, Limoeiro, Machados, Orobó, Palmeirina, Sairé, São João, and São Joaquim do Monte do produce orange and lime.

On the other hand, the municipalities Agrestina, Alagoinha, Caetés, Calçado, Canhotinho, Cupira, Jucati, Jupi, Jurema, Lagoa do Ouro, Lagoa dos Gatos, Panelas, Paranatama, Pesqueira, Poção, Salgadinho, Saloá, Sanharó, Santa Maria do Cambucá, São Bento do Uma, São Vicente Férrer, Surubim, Terezinha, and

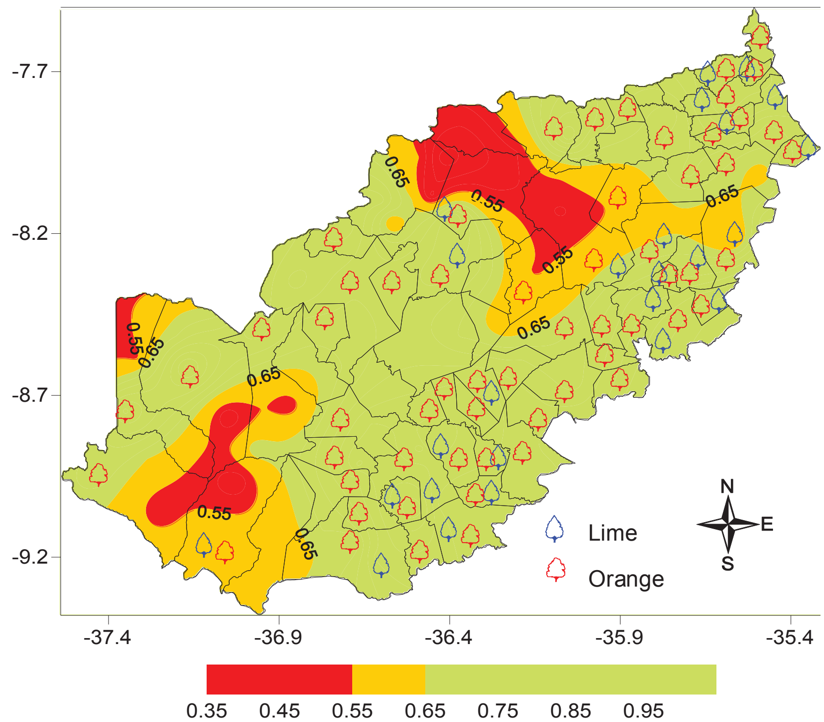

Figure 8. Map of agro-climatic zones with citrus producer municipalities in the Agreste region of Pernambuco State, Brazil.

Vertentes only produce oranges. There are still six municipalities under low climatic risk that do not have citrus production, as follows: Capoeiras, Casinhas, Frei Miguelinho, Ibirajuba, Venturosa, and Vertente do Lério.

We may state that the citriculture satisfactory yield in Agreste depends either on varieties resistant to the dry season, or on an alternative management of soil coverage to reduce the evaporative demand. There accesses moderately tolerant and intolerant to dry for cultivation in Brazil (Nascimento et al., 2012; Suassuna et al., 2012; Smith et al., 2015), most using rootstock of Santa Cruz Rangpur lime (Citrus limonia Osbeck).

Comparing maps of agro-climatic zones, Water Deficit, and Water Excess, we observe that, for WRSI < 0.65, DEF varies from 600 to 900 mm. Similarly, WRSI ≥ 0.65 is found where either DEF < 500 mm per year or there is EXC. In zones of moderate climatic risk, i.e., WRSI between 0.55 and 0.65, there is an annual water deficit ranging from 500 to 600 mm; Vale do Ipanema that is located southwest of Meridional Agreste DR, and northwestern Vale do Ipojuca present the largest areas under these characteristics.

Analysis of the map comprising 60 citrus producer municipalities in Agreste (IBGE, 2007), and agro-climatic zones for AWC of 50 mm, indicates that 44 municipalities that produce lime and/or orange are located in favorable agro-climatic zones, with low climatic risk; however, 16 of them are either in intermediate or adverse agro-climatic zones, with moderate to high climatic risk, the latter presenting great water deficit varying from 600 to 900 mm (Figure 8).

Therefore, there are satisfactory conditions for the development of citriculture in the Agreste region of Pernambuco State as indicated by favorable agro-climatic zones in green, comprising 50 municipalities (Figure 8). Among those that do have citrus cultivation, mean yield of oranges and limes is 35.8 and 39.8 t ha^{-1}, respectively (IBGE, 2007).

In the intermediate zones, in yellow, that covers 16 municipalities (Figure 8), mean yield of oranges and limes is 30 and 25 t ha^{-1}, respectively (IBGE, 2007). Five municipalities are under high climatic risk. It is notorious that orange and lime production is favored in Brejo Pernambucano, Médio Capibaribe, and Garanhuns microregions, which areas present water excess around 950 mm.

Conclusions

In Agreste mesoregion, Pernambuco State, Brazil, the annual temperature variation, with minimum of 16.4°C and maximum of 33.4°C, is not considered a thermal factor of risk for citrus production.

Considering Agreste agro-climatic conditions, there are more than 12,000 km^2 favorable for citrus cultivation, what is a significant area to be explored, once the current cultivated locations comprise less than 0.5% of that total.

Water excess of around 950 mm, or water deficit lower than 500 mm per year, are not limiting factors for citrus cultivation. In Pernambuco Agreste, 50 municipalities are in favorable agro-climatic region, with small climate risk; 16 in the intermediate agro-climatic region, with average risk and 5 in unfavorable agro-climatic region with high climatic and high water deficit risk.

Conflict of Interest

The authors have not declared any conflict of interests.

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Vol. 10(25), pp. 2516-2531, 18 June, 2015
DOI: 10.5897/AJAR2013.7542
Article Number: 785AB5453517
ISSN 1991-637X

http://www.academicjournals.org/AJAR

African Journal of Agricultural Research

Full Length Research Paper

Morphological, physical and chemical properties of soils associated in toposequence forestablishing taxonomy classes in Pratapgarh District of Rajasthan, India

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Received 26 June, 2013; Accepted 19 May, 2015

The present study was conducted to study the variability in soil properties in relation to landforms, in the present investigation, two transects that is, Aravalli mountain ranges and Malwa plateau, were selected in the Pratapgarh district having eight landforms namely hill, pediments, valley, and plain in the Aravalli Mountain ranges and Malwa plateau, respectively. Total eight pedons were examined in the field and investigated in the laboratory using standard laboratory procedures. The soils on hill top and pediment were shallow, gravely sandy loam to clay loam single grain in texture with medium coarse weak sub angular blocky structure and exhibited dark yellowish brown to dark reddish brown colour. The soils of valley were deep, sandy loam to loam and silty clay loam to clay loam in texture with medium coarse weak sub angular blocky to medium fine moderate sub angular blocky structure and exhibited dark yellowish brown to dark reddish brown colour. The soils of plain were found deep, silty clay in texture with medium moderate to strong angular structure (angular and sub angular) and exhibited dark brown to very dark grayish brown colour. The available water capacity were recorded higher in the plain soils as compared to soils of other landforms as well as in Aravali mountain ranges and Malwa plateau. The pH was relatively higher in the soils of Aravali mountain ranges than Malwa plateau but EC was relatively lower in the soil of Aravali mountain ranges then Malwa plateau. Distribution of organic carbon was low in soils of all pedons but comparatively higher in soils of Malwa plateau. Base saturation was comparatively lower in the soils of lower topographic position. Cation exchange capacity was found positively correlated with clay and increases as clay increased down the slope as well as with depth. Concentration of exchangeable bases was in order of Ca^{2+}>Mg^{2+}>K^{+}>Na^{+} in all the pedons soils.

Key words: Toposequence associated soil, morphological, physical, chemical properties, taxonomy.

INTRODUCTION

Pratapgarh is newest constituted district of Rajasthan state, which is a tribal dominant with an area of 411736 ha. Pratapgarh is situated in the southern part of Rajasthan. It is situated on the junction of Aravali mountain ranges and the Malwa Plateau; hence characteristics of both are prominent in the area.

Pratapgarh is located at 29.03° North and 74.78° East. It has an average elevation of 491 m (1610 feet).

The western, southern and northern parts of the district are somewhat plains. North and southern part of the district having black cotton soil in abundance. The major irrigation project of the district is the Jakham Dam. The north-west part of this region had dense forests. In the traditional method of soil map compilation, much emphasis is not being given on study of variability in pedogenic factors and quantification of soil properties used for soil classification. As such the information, dealing with variability in genetic related soil properties and their relationship with properties, which have key role in natural resource management, is generally scanty in India and so particularly in context to Rajasthan. Besides, sound and reliable database, dealing with information is needed to prepare base line of indicators to maintain the sustainability of system. So, detailed studies on morphological, physical and chemical properties are required to comprehend the extent of soil variability and to optimizing land use in Pratapgarh district. The present investigation is taken up to study the pathways of soil formation in relation to topography.

MATERIALS AND METHODS

Physical characteristics

Particle size description

International pipet method as described by Black (1980) was followed for estimation of various soil separates. Texture of the soil sample was determined from the composition of separates using triangular chart.

Bulk density

Piper (1950), Keen Reczowasky method was followed.

Particle density

Pycnometer was used to determine volume and weight of soil particle as per method described by Black (1965).

Total density

Percent pore space was calculated by using the following formula:

Percent porosity = 100 (1 - Bulk density /particle density).

Maximum water holding capacity

Piper (1950), Keen Reczowasky method was adopted.

Available water capacity (m^3/m^3)

Gravimetric water content ($m^3/m^{3)}$ at 0.03 Mpa and at 1.5 Mpa (Srivastava et al., 1998).

Phsico-chemcial and chemical determinations

pH

pH was determined in 1:2.5 soil water suspension using glass electrode pH meter as per description of Richard (1954).

Electrical conductivity

Electrical conductivity of 1:2.5 soil water suspensions was determined by using solubridge as described by Richard (1954).

Organic carbon

Walkley and Black rapid titration method was followed as outlined by Jackson (1979).

Calcium carbonate

Acid neutralization method as outlined by Allison and Moddie (1965) was adopted.

Cation exchange capacity

Cation exchange capacity was determined using 1 N neutral ammonium acetate method as described by Richard (1954).

Exchangeable cations: Calcium

In the ammonium acetate leachat, calcium was determined by titrating with versenate solution as per method described by Richard (1954).

Magnesium

The exchangeable Mg was calculated by subtracting the values of Ca from the Ca + Mg as described by Richard (1954).

Sodium

In ammonium acetate extract, sodium was determined flame photo metrically.

Potassium

In ammonium acetate extract, potassium was determined flame photo metrically.

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Table 1. List of standards procedures for laboratory investigations.

S/No.	Soil properties	Methods	References
(A)	**Physical properties**		
1.	Mechanical analysis	International pipette method	Piper (1950)
2.	Bulk density	Core sampler method	Richards (1954)
3.	Particle density	Pycnometer method	Richards (1954)
4.	Water retention characteristics	Using pressure plate apparatus	Richards (1954)
5.	Available water capacity (m^3/m^3)	Gravimetnic water content m^3/m^3 at 0.03 MPa and at 1.5 MPa	Srivastava et al. (1998)
6.	Maximum water holding capacity	Keen Reczowasky method	Piper (1950)
7.	Percent porosity	100 (1-BD/PD)	Richards (1954)
(B)	**Phsico-chemcial and chemical determinations**		
8.	pH	Using 1:2 soil water and 1 N KCl suspension glass electrode pH meter	Richards (1954)
9.	Electrical conductivity (dSm^{-1})	1:2 soil water extract using solubridge	Richards (1954)
10.	Exchangeable cations (Ca^{+2} mg^{+2})	Versenate titration method	Richards (1954)
11.	Exchangeable cations (K^+ Na^+)	By 1 N ammonium acetate extract method	Richards (1954)
12.	Cation exchange capacity of soils	By 1 N ammonium acetate extract method	Richards (1954)
13.	Organic carbon	Walkley and black wet digestion method	Jackson (1979)
14.	Calcium carbonate	Acid neutralization method	Allison and Modi (1965)

RESULTS AND DISCUSSION

Morphologial features

Soil morphology or pedomorphic features has been studied mainly under field conditions. The morphology of a soil can be best evaluated from the *in-situ* examination of the soil profiles. The pedomorphic features of the soil profiles are the mirror image of the processes as responsible for the formation of a particular type of soil. Soil morphology is the stepping stone to the thorough appreciation of the physical, chemical and biochemical properties of the soil (Tables 1 and 2).

Soil colour

The colour of the soils ranged between very dark gray brown (10YR 3/1) to dark reddish brown (5YR 2.5/2) In Aravali mountain ranges, the colour variation was observed from brown (10YR 4/3) to dark brown (7.5YR 3/2). In case of soils of Malwa plateau colour was found varies from very dark grayish brown (10YR 3/1) to dark reddish brown (5YR 2.5/2). The colour of Aravali mountain range soils was brown to dark brown in almost all samples. And in case of soils of Malwa plateau the colour of soils of higher topographic positions (hill top, pediment and valley) varied from dark reddish brown (5YR 2.5/2) to yellowish brown (7.5YR 4/4), while plain soils were ranged in colour from very dark gray (10YR 3/1) to very dark grayish brown (10YR 3/2).

After thorough examination of data (Table 2) it was observed that the soils of hill top in Aravali mountain ranges showed a shade of dark yellowish brown and as topography gets gentler the colour of soil becomes brown (10YR 4/3) or dark brown (7.5YR 3/2) in plain. It was also found that the colour of surface horizon was brighter then lower horizons. While in case of soils of Malwa plateau it was observed that hill top soil and valley soils showed dark reddish brown in all upper horizon and radish brown in lower most horizon of both transect and in pediments it found dark brown (7.5YR/3/2) while in plain it found very dark gray (10YR 3/1) in upper and (10YR 3/2) very dark grayish brown in lower horizons. Maximum samples in both transect were found under the category of dark yellowish brown followed by dark brown colour. Similar pattern of soil colour variation were also reported by Rajkumar et al. (2005) and Sarkar et al. (2001).

Depth of soil solum

Solum thickness is a combined expression of pedogenetic horizons and varied from 50 to 75 cm and

Table 2. Salient morphological features.

Profile	Depth (cm)	Horizon designation	Colour (moist)	Texture	Gravel volume (%)	Structure	Reaction with HCl 0.01 N
			I Aravali Mountain Ranges				
			Hills (Dipora)				
P_1	0-30	Al	10 YR 4/4	Gsl	40-50	sg	-
			Pediments (Lodiya)				
P_2	0-20	A1	10 YR 4/3	L	10	mc_1sbk	-
	20-50	C	10 YR 4/3	Gcl	>80	mc_1sbk	-
			Valley (Bhagadera)				
P_3	0-15	Ap	10YR 4/4	Sl	-	mc_1sbk	-
	15-31	A2	10YR 4/3	Sil	-	mc_1sbk	-
	31-48	Bw1	10YR 4/3	Cl	-	m_2sbk	-
	48-75	C	10YR 4/3	L	-	mf_2sbk	-
			Plain - (Charpotiya)				
P_4	0-12	AP	7.5YR 4/3	Sic	-	m_2sbk	E
	12-20	Bw1	7.5YR 4/3	Sic	-	m_2abk	Es
	20-32	Bw2	7.5YR 4/3	Sic	-	m_2abk	Es
	32-40	Bw3	7.5YR 3/2	Sic	10	m_2abk	Es
	40-55	Bw4	7.5YR 3/2	Gsic	20	m_2abk	Es
	55-70	Ck	7.5YR 3/2	Weathered material of schist			Es
			II Malwa Plateau				
			Hills (Chiklad)				
P_5	0-15	A1	5YR 3/4	Sl	15	sg	-
	15-40	C	5YR 4/4	Gsl	>80	sg	-
			Pediments (Shah ji ka pathar)				
P_6	0-18	A1	7.5YR 3/2	L	10	f_2sbk	-
	18-30	Bw	7.5YR 3/4	Cl	10	f_2sbk	-
	30-50	C	7.5YR 4/4	Cl		f_1sbk	-
			Valley (Ghotarsi)				
P_7	0-12	Ap	5YR 2.5/2	Sicl	-	mf_1sbk	Es
	12-30	Bw1	5YR 4/3	Sil	-	mf_1sbk	Es
	30-45	Bw2	5YR 4/3	Cl		mf_2sbk	Es
	45-80	Bw3	5YR 4/4	Cl		mf_2sbk	E
			Plain - (kuni)				
P_8	0-10	Ap	10YR 3/1	Sic		m_1abk	Es
	10-25	Bss1	10YR 3/1	Sic		m_2abk	Es
	25-45	Bss2	10YR 3/2	Sic		m_3abk	Es
	45-60	Bss3	10YR 3/2	Sic		m_3abk	Es
	60-80	C	10YR 3/2	Sic		m_3abk	Es

40 to 80 cm in Aravali mountain ranges (P_1-P_4) and Malwa plateau (P_5-P_8), respectively (Table 2). Soils of Aravali mountain ranges were very shallow on pediments (P_2) and shallow on hill top (P_1) while remaining soils of Aravali mountain ranges on valley (P_3), plain (P_4) were deep. Whereas soils of Malwa plateau were very shallow on hill top (P_5), shallow on pediments (P_6), while the remaining soils of Malwa plateau on valley (P_7), plain (P_8)

were moderately deep. Gentle to moderate slope, rapid runoff and severe erosion account for very shallow to shallow soils on the elevated segment of transect. These altogether cast rapid removal of weathering product from the site of formation, resulting in shallower depth of soils. Sidhu et al. (2000), Rathore (2003) and Singh (2004) also reported shallow soils at higher elevation. However, shallow depth in very gently sloping alluvial plain must be due to resistance of parent material to weathering, which prevents soil development and its accumulation. Therefore, the depth of soils was found to be a function of the topography, type of basement rock and configuration of the landscape.

Texture

The variation in soil texture of different landforms is shown in Table 2. The soils of Aravali mountain ranges were gravel sandy loam on hill top (P_1), Loam at the surface and gravel clay loam in sub surface of pediment (P_2), all horizons having different texture (sandy loam to loam) in valley (P_3) while clayey in charpotiya (P_4). Malwa plateau had sandy loam to gravel sandy loam on hill top soil (P_5), and loam to clay loam in pediment (P_6), silty clay loam at the upper surface and clay loam in sub surface of valley (P_7) had sandy clay loam texture. In case of pedon of plain (P_8) the texture was found silty clay. The variation in the intensity of erosion and deposition explains the variation in soil texture topographically. Thus the variation in type of parent rock, the portions on the landscape and the some from where the matter is carried by flowing water determine the texture as a function of topography. As a result of rapid downward movement of rain water, the finer particles were readily carried away toward the lower areas while coarse particles remain. This could be attributed as a main reason for the behavior of texture with change of slope. Similar results were also observed by Gupta et al. (1999), Sarkar et al. (2001) and Maji et al. (2005).

Soil structure

Single grain structure was the feature of soils associated with the hill top of Aravali mountain ranges. The structure become medium coarse weak sub angular blocky in the soils of pediment and upper horizon of pedon P_3 while the soils of pedon P_4 had medium moderate sub angular blocky in upper horizon and in subsequent horizons the structure become medium moderate angular blocky. The structure of lower horizons of pedon P_3 exhibit medium moderate fine sub angular blocky arrangement.

The soils of Malwa plateau associated with the hill top had single grain structure. The structure become moderately fine sub angular blocky in the soils of pediment. It was found medium weak fine sub angular blocky in upper layers and in subsequent layers it become medium moderate fine sub angular blocky in soils of valley. The soils of plain (P_8) had medium moderate to strong angular blocky structure.

Lime concretions and effervescence

The extent of distribution of calcareousness (reaction to dilute HCl) over different physiographic units is shown in Table 2. The data reveal that calcareousness was uniform and throughout in soils of plain pedon (P_4) in Aravali mountain ranges and valley and plain pedons (P_7, P_8) in Malwa plateau soils evident by the reaction with dilute HCl being slight to violent effervescence in all these pedons. While in pedon P_1 it was seen non-effervescent in the surface layer that is, A1. In rest of the pedons which occurring on elevated topographic position, no reaction was observed with dilute HCl, indicating that these soils were either free of calcareousness or the content was too low to be detected by dilute HCl.

Horizon designation

Absence of cultivation over the surface was designated as AI (P_1, P2, P_7 and P_8). A2 was allocated to the horizon, having slight improvement in soil structure in term of grade and angularity (P_3). Those soils which were under cultivation and leaves of stubble at the surface which are ploughed before sowing of every crop. As such, surface horizons were therefore designated as Ap horizon that is, plough layer. Bw is given to layer which show some evidence of development either due to increase in clay content , formation of well defined peds or some reddening of hue (P_3, P_4, P_6 and P_7,). Bss horizons are the mark of slickenside presence (P_4, and P_8). Slickensides are formed as a result of the swelling of clay minerals and shear failure, commonly at angle of 20 to 60 degree above horizontal. C horizon is marked for weathered material in pedons P_2-P_8 except P_4 and P_7 where it was designated as Ck due to accumulation of carbonates.

PHYSICAL PROPERTIES

Results pertaining to mechanical composition, bulk density, porosity and water retention characteristics of soils associated in both transect namely Aravali mountain ranges and Malwa plateau, are described in this section while data on these features are elucidated in Tables 3 to 5.

Mechanical composition

Relative proportions of sand, silt and clay in soils of both

Table 3. Physical properties – Mechanical composition in soils of various land forms.

Pedons	Horizon designation	Mechanical composition (%) Sand (Size in mm) Very coarse 2.0-1.0	Coarse 1.0-0.5	Medium 0.5-0.25	Fine 0.25-0.1	Very fine 0.1-0.05	Total Sand 0.05-2.0	Silt 0.05-0.002	Clay <0.002
				I Aravali Mountain Ranges					
				Hill (Dipora)					
P1	Al	4.63	5.32	8.51	14.68	18.53	51.67	32.26	16.07
				Pediments (Lodiya)					
P2	Wt. mean	3.43	6.41	7.36	9.92	11.06	38.19	35.41	26.38
				Valley (Bhagadera)					
P3	Wt. mean	0.08	0.59	2.77	19.79	20.92	44.09	32.83	22.94
				Plain (Charpotiya)					
P4	Wt. mean	0.18	0.32	0.63	2.58	6.27	9.85	42.51	47.51
				II Malwa Plateau					
				Hill (Chiklad)					
P5	Wt. mean	0.17	0.78	13.51	38.72	5.92	59.15	20.14	20.77
				Pediments (Shah ji ka pathar)					
P6	Wt. mean	0.37	1.30	3.36	28.10	11.80	44.93	24.28	30.79
				Valley (Ghotarsi)					
P7	Wt. mean	0.33	2.12	1.95	3.23	14.54	22.17	48.31	29.52
				Plain (Kuni)					
P8	Wt. mean	0.41	1.08	2.42	4.36	6.28	14.56	40.35	42.50

transect are presented in Table 3.

Sand

Total sand content of all pedons in Aravali mountain ranges ranged from 8.09 to 51.67% with a weighted mean value of 35.95%. The content was highest in the soils associated with hill (P_1) followed by valley (P_3), pediments (P_2), while it was lowest in the soils of plain (P_4). However, in general, fine sand fraction dominates over the different sand fractions of all the profiles. Generally, soil texture was coarser on the higher landforms or sloping landforms, because the fine materials like silt and clay are removed from the relatively higher location to those portion where slopes become gentler attain heavily level relief. In soils of Malwa plateau transect, total sand content ranges from 12.09 to 62.51% with a weighted mean value of 35.75%. The sand content was higher in the soils on hill top (P_5) and pediments (P_6), while it was lower in the soils of plain (P_8). However, valley (P_7) and had intermediate amount of sand. By and large fine sand fraction on higher elevation, dominates over other fraction while on lower elevation, very fine sand fractions were dominant over fine sand. Similar results were also reported by Singh (2004).

Silt

The content of the silt in the soils of Aravali mountain ranges varied between 31.47 to 43.87% with a weighted mean value of 35.75%. Highest average silt observed in soils of plain (P_4). While lowest average found in soils of hill top (P_1) followed by valley (P_3). While the soils of pediment (P_2) exhibited intermediated trend of percent silt contribution toward the mechanical composition of these soils. In the soils of Malwa plateau transect, it was observed that the silt content varied between 19.21 to 60.00% with a mean value of 33.27% with highest

Table 4. Physical properties: Bulk density, particle density and porosity in soils of various land forms.

Pedons	Horizon designation	BD	PD	Porosity (%)
		Mg m^{-3}		
	I Aravali Mountain Ranges			
	Hill (Dipora)			
P1	Al	1.45	2.56	43.35
	Pediments (Lodiya)			
P2	Wt. mean	1.52	2.57	40.95
	Valley (Bhagadera)			
P3	Wt. mean	1.61	2.61	37.93
	Plain (Charpotiya)			
P4	Wt. mean	1.57	2.54	38.29
	II Malwa Plateau			
	Hill (Chiklad)			
P5	Wt. mean	1.40	2.63	46.59
	Pediments (Shah ji ka pathar)			
P6	Wt. mean	1.36	2.60	47.84
	Valley (Ghotarsi)			
P7	Wt. mean	1.51	2.61	42.29
	Plain (Kuni)			
P8	Wt. mean	1.51	2.60	41.93

average value in valley (P_7) followed by plain (P_8) and lowest average value in hill top (P_5) followed by pediment (P_6) soils. An increasing trend of higher silt content from elevated topographic position to lower topographic position as well as along with down the depth of pedons was observed which could be because of movement of silt particles along with downward movement of water as well as due to erosion agents.

Clay

The clay content varied from 16.07 to 49.75% in soils of Aravali mountain ranges with a mean value 28.22%. The highest average value of clay content was observed in the soils of plain (P_4). Whereas lowest value of clay content was in the soils of hill top (P1). The soils of pediment (P_2) and valley (P_3) were found intermediate in clay content. While in case of soils of Malwa plateau, clay content varied from 18.46 to 44.95% with mean value 30.89%. The highest average value of clay content was observed in the soils of plain (P_8) followed by pediment (P_6), and valley (P_7) whereas lowest value of clay content was in the soils of hill top (P_5). The higher clay content down the slope was also reported by Sarkar et al. (2001).

Physical properties

Bulk density

Bulk density is a reliable index for determining the presence of compact layers particularly in the subsoil. An examination of data, presented in Table 4 indicates that values of bulk density increase with the depth of the soil. Bulk density of soils in Aravali mountain ranges between 1.45 to 1.65 mg m^{-3} with a weighted mean value of 1.53 mg m^{-3}. The highest value of bulk density (1.65 mg m^{-3}) was observed in Bw_1 horizon of valley (P_3). Whereas the lowest value of bulk density (1.45 mg m^{-3}) was observed in the soils of hill top (P_1). In case of soils of Malwa plateau, bulk density varied from 1.33 to 1.62 mg m^{-3} with a weighted mean value 1.44 mg m^{-3}. The highest value of bulk density (1.62 mg m^{-3}) was observed in C horizon of plain (P_8) whereas the lowest value (1.33 mg m^{-3}) in soils of pediment (P_6). In generally an increase in bulk density in the subsurface horizons was observed in all the pedons examined along both transect. Chaudhary et al. (2005) while studying the soils of Himalayas also found similar results of increasing trend of B.D. with depth.

Particle density

It is evident from the data presented in Table 4 that the particle density of the soils of Aravali mountain ranges was found to range between 2.52 to 2.65 mg m^{-3}. While in case of soils of Malwa plateau, particle density varied from 2.55 to 2.64 mg m^{-3}. It was found to increase with depth but such an increase was only up to a certain depth of various landforms followed by decrease. Particle density was found higher in the soils of Malwa plateau as compared to the soils of Aravali mountain ranges which suggest heterogeneity in profile development in Malwa plateau. Similar trend was also recorded by Veerpal (1976), Datta et al. (1990) and Singh et al. (1999).

Porosity

The packing pattern of soil fragment determines the porosity of the soils. The porosity of various pedon ranged between 35.79 to 43.35% with a weighted mean value of 40.13 in soils of Aravali mountain ranges. While in soils of Malwa plateau, it was ranged between 37.93 to 48.85%. The maximum value of porosity was recorded in A1 layer of hill top (P_1) while minimum value was recorded in ck horizon of plain soils in Aravali mountain ranges. In case of Malwa plateau soils the maximum value was observed in the Ap horizon of hill top soils while minimum value was recorded in C layer of plain (P_8). This difference was mainly due to variation in silt and sand fractions and their arrangement or shape of orientation at different locations of the transect. Generally the porosity was high in surface horizons and decreases with depth (Table 4) which may be due to higher value of bulk density in subsurface soils. Similar observations were also reported by Wick and Whiteside (1959); Rathore (1993) and Sharma (1994). Further, the bulk density and porosity were inversely related which is also supported by the findings of Kolarkar et al. (1974), Rathore (1993) and Sharma (1994).

Moisture retention characteristics

The data on the effect of different landform on water retentions characteristics are presented in Table 5. It was seen from the data that the amount of the water retained at 0.03 MPa ranged from 0.25 to 0.49 m^3/m^3 with a weighted mean value of 0.35 m^3/m^3 in soils of Aravali mountain ranges. Water retention was recorded highest, ranging from 0.43 to 0.49 m^3/m^3 with a weighted mean value 0.46 m^3/m^3 in the soils of plain (P_4) followed by valley (P_3). Lowest water retention was recorded in soils of hill top (P_1) followed by pediments (P_2). Whereas in case of soils of Malwa plateau, water retention at 0.03 MPa ranged from 0.19 to 0.52 m^3/m^3 with a weighted mean value of 0.30 m^3/m^3. Water retention was highest, ranging from 0.41 to 0.52 m^3/m^3 (mean value 0.45 m^3/m^3) in soils of plain (P_8) followed by valley (P_7). The water retention in remaining pedon was in pediment>hill top soil sequence.

The water retention at 1.5 MPa also followed the similar trend, ranging from 0.10 to 0.26 m^3/m^3 with a weighted mean value of 0.16 m^3/m^3 in soils of Aravali mountain ranges whereas corresponding value are slightly higher 0.05 to 0.29 m^3/m^3 with a weighted mean value of 0.14 m^3/m^3 in soils of Malwa plateau. indicated that an increase in clay and silt content had contributed marginally towards the available water capacity due to corresponding increase in water retention at both levels that is, 0.03 and 1.5 MPa suction pressures. The amount of water retained was found to be higher in subsurface layer in comparison to surface layer in both transects. Similar observations were made by Nagar et al. (1995) and Balpande et al. (2007).

Available water capacity (AWC) volume basis

Available water capacity is an important indicator for sowing seed/or crop planning, irrigation scheduling and crop selection under rainfed conditions/areas like Pratapgarh district. Available water capacity is the difference of water content at 0.03 and 1.5 MPa suction pressures. Available water capacity was varying from 0.14 to 0.24 m^3/m^3 with a weighted mean value of 0.19 m^3/m^3 in the Aravali mountain ranges. Maximum available water capacity observed in plain (P_4) followed by valley (P_3) and hill top (P_1), whereas lowest value comes under pediments (P_2). While in case of Malwa plateau, available water capacity was ranged from 0.13 to 0.24 m^3/m^3 with weighted mean value 0.16 m^3/m^3. Maximum available water capacity in this transect was observed in plain (P_8) followed by valley (P_7) and whereas lowest value comes under pediments and hill top (P_1 and P_2). It was observed that soils of Malwa plateau had more available water content compare to soils of Aravali mountain ranges which could be attributed to the relatively higher finer fraction in these soils.

Water holding capacity (WHC)

The water holding capacity ranges from 23.56 to 40.11% where maximum water holding capacity found in plain (P_4) and minimum in pediments (P_2) in Aravali mountain ranges. In case of Malwa plateau maximum water holding

Table 5. Physical properties : Moisture characteristics of soils.

Pedons	Horizon designation	Moisture retention (m^3/m^3) on suction 0.03 MPa	1.5 MPa	AWC (m^3/m^3)	WHC (%)
		I Aravali Mountain Ranges			
		Hill (Dipora)			
P_1	AI	0.32	0.10	0.22	37.55
		Pediments (Lodiya)			
P2	Wt. mean	0.28	0.15	0.13	24.28
		Valley(Bhgadera)			
P3	Wt. mean	0.36	0.16	0.21	31.59
		Plain (Charpotiya)			
P4	Wt. mean	0.46	0.24	0.22	34.64
		II Malwa Plateau			
		Hill (Chiklad)			
P5	Wt. mean	0.20	0.08	0.13	33.28
		Pediments (Shah ji ka pathar)			
P6	Wt. mean	0.23	0.09	0.13	34.61
		Valley (Ghotarsi)			
P7	Wt. mean	0.34	0.15	0.18	27.52
		Plain (kuni)			
P8	Wt. mean	0.45	0.24	0.22	32.09

capacity found 41.11% in pediments (P_6) and minimum in valley (P_7).

CHEMICAL PROPERTIES

In order to understand the specificity of relationship between the soils and physiography it is imperative to analyze the results of various chemical properties in light of micro-topographical variations imposed by variations in landforms.

Soil reaction (pH)

Soil reaction (pH) is one of the important parameter controlling availability of plant nutrients in the soils. In the present investigation the pH of the soils in Aravali mountain ranges was between 6.92 to 7.72 with a mean value of 7.43 indicating that the soils are near neutral to slightly alkaline (Table 6). In soils of Malwa plateau, the pH ranged between 6.03 to 7.75 with a mean value 6.92. It was near neutral in the soils of hill top pedon P_1 (6.03) and moderately alkaline in the soils of plain pedon P_8 (6.92 to 7.59). A critical examination of data indicates that soil pH in most cases was found to increase with depth in both transects. This increase level of pH down the depth of pedons was mainly due to movement of soluble salts and increased content of calcium carbonate. The higher pH values in soils of lower slopes and its increased value with soil depth could be attributed to the deposition of illuviated bases from surrounding upper slopes. Similar results were also observed by Dutta et al. (1990), Deshmukh and Bapat (1993), Rathore (1993), Sharma (1994) and Chamuah et al. (1996).

Electrical conductivity (EC)

EC is a measure of concentration of soluble salts in the soil at any temperature and it was determined in soil: water, 1:2 suspension and data presented in Table 6. The electrical conductivity was found range between 0.32 to 1.26 dSm^{-1} with a mean value of 0.56 dSm^{-1} in soils of

Table 6. Chemical properties: pH, EC, organic carbon and $CaCO_3$.

Pedons	Horizon designation	pH (1:2)	EC (dSm^{-1})	OC ($g\ kg^{-1}$)	$CaCO_3$ ($g\ kg^{-1}$)
		I Aravali Mountain Ranges			
		Hill (Dipora)			
P_1	Al	7.33	0.56	7.85	0.00
		Pediments (Lodiya)			
P2	Wt. mean	7.41	0.40	4.29	0.00
		Valley (Bhagadera)			
P3	Wt. mean	7.46	0.61	2.70	0.00
		Plain (Charpotiya)			
P4	Wt. mean	7.55	0.70	2.42	86.14
		II Malwa plateau			
		Hill (Chiklad)			
P5	Wt. mean	6.04	0.44	5.19	0.00
		Pediments (Shah ji ka pathar)			
P6	Wt. mean	7.13	0.98	5.01	0.00
		Valley (Ghotarsi)			
P7	Wt. mean	7.14	1.25	5.54	126.21
		Plain (Kuni)			
P8	Wt. mean	7.38	0.97	4.32	92.04

Aravali mountain ranges. Maximum average electrical conductivity was recorded in plain (P_4). While in case of Malwa plateau, electrical conductivity was found to range between 0.32 to 1.97 $dSm^{-1}$with a mean value 0.91 dSm^{-1}. The general trend of soluble salt distribution was found increasing from upper rolling topographic position to lower elevation, indicates that the appreciable amount of salts moved down the slope along with flowing water. The findings are in line with the results of Gaikawad et al. (1974), Dutta et al. (1990) and Sharma (1994).

Organic carbon

The organic carbon content of the soils is an indication of nitrogen status. In the soils of the Aravali mountain ranges, organic carbon content was found to range between 1.35 and 7.85 g kg^1 with a weighted mean value of 4.31 g kg^{-1}. It was minimum in soils of plain P_4 followed by valley P_3 and pediments P_2 (weighted mean value 2.42, 2.70, and 4.29 g kg^{-1}) respectively, and maximum in soils of hill top (7.85 g kg^{-1}). In the soils of Malwa plateau, the organic carbon content was found to range between 2.35 to 9.50 g kg^{-1} with a weighted mean value of 5.01 g kg^{-1}. No specific trend of distribution has emerged out with respect to the topography in the soils selected for the study. In general the content of organic carbon is higher at the surface, decreasing down the depth in soil profile. This was mainly due to accumulation of plant residues on the soil surface and very less opportunity to move it down the depth due to rapid decomposition at higher temperature and inadequate pedoturbation. Almost all soils were low in organic carbon (<5 g kg^{-1}) content except soils of pedon P_1 in Aravali mountain ranges and pedon (P_5-P_7) in Malwa pateau, and it was mainly due to rapid rate of mineralization at higher temperature and adequate soil moisture level. The organic carbon distribution is mainly associated with physiography and land use. Similar results were also observed by Sharma et al. (1999), in soils of Haldi-Ghati region of Rajasthan (Walia and Rao, 1996).

Calcium carbonate

In present investigation, the content of calcium carbonate of both transect is shown in Table 6. It can be seen that the content of calcium carbonate in Aravali mountain ranges ranged between 0.00 to 175.40 g $kg^{-1}$with a weighted mean value 86.14 g kg^{-1}. While in Malwa plateau, its content ranged between 0.00 to 146.40 g $kg^{-1}$with a weighted mean value 109.12 g kg^{-1}. It was observed that calcium carbonate content in higher topographic positions that is, hill and pediment (P_1, P_2 and P_5, P_6) in both transects was found absent throughout whole profile which could be ascribed to the completely leached out of the profile as well removal of calcium carbonate and its subsequent deposition in lower topographic positions. The increasing trend for calcium carbonate content was found to be associated with decreasing topographic positions. A specific regular trend of distribution of calcium carbonate has emerged out with respect to the topography (hill top to plain) in the soils of Aravali mountain ranges and Malwa plateau.

In cases of both transect, the surface layer contained lower/ nil values of calcium carbonate which gradually increased down the depth of profile. This was due to downward movement of calcium ions and precipitated in subsurface layers at higher pH level. An increasing trend of calcium carbonate with depth was registered in some soils of Udaipur and Chittaurgarh districts of Rajasthan by Singh et al. (1999). Similar observations were also recorded by Maji et al. (2005) and Kumar and Prasad (2010).

Exchangeable cations

A critical examination of data from Table 7 revealed that exchangeable calcium was the dominant cation followed by magnesium, potassium and sodium in soils of both transect. Exchangeable calcium, magnesium, potassium and sodium ranged between 5.86 to 22.05, 4.08 to 12.60, 0.18 to 0.89 and 0.44 to 0.95 C mol (p^+) kg^{-1} with a weighted mean value of 12.65, 7.09, 0.60 and 0.72 C mol (p^+) kg^{-1}, respectively in soils of Aravali mountain ranges. The soils of plain (P_4) had maximum average exchangeable calcium, magnesium, sodium and potassium. The soils of pediments (P_2), valley (P_3) hill top (P_1) come next with respect to these cations. In case of Malwa plateau, exchangeable calcium, magnesium, sodium potassium and ranged between 7.04 to 23.35, 6.07 to 12.05, 0.35 to 1.55 and 0.42 to 1.32 C mol (p^+) kg^{-1} with a weighted mean value of 15.98, 8.62, 0.8 and 0.84 C mol (p^+) kg^{-1} respectively. Exchangeable calcium was higher (23.35 C mol p^+ kg^{-1}) in soils of plain (P_8) followed by pediments pedon P_6 [20.60 C mol (p^+) kg^{-1}]. The exchangeable magnesium was followed the same trend of distribution. No specific trend of distribution has emerged out with respect to the exchangeable potassium and sodium. Calcium was dominant cation followed by magnesium, potassium and sodium also reported by Maji et al. (2005). The higher content of exchangeable calcium in soils of lower plains of Aravali mountain ranges had been attributed to the presence of dolomitic parent materials which contributes most of the calcium ions in runoff water which carry them to deposit in the soils of lower landforms and to the movement of bases from the upper part of transect to lower one, which are carried with the moving finer fractions of soils under influence of erosion, Walia and Chamuah (1994) also recorded higher base saturation at the lower topographical position.

Cation exchange capacity

Data pertaining to cation exchange capacity of soils are presented in Table 7 Cation exchange capacity in different pedons found to vary between 12.20 to 40.07 C mol (p^+) $kg^{-1}$with a weighted mean value of 22.44 C mol (p^+) kg^{-1} in soils of Aravali mountain ranges. The maximum value of CEC, observed in soils of plain P_4 [40.07 C mol (p^+) kg^{-1}] and lowest value [12.20 C mol (p^+) kg^{-1}] in valley pedon P_3 followed by hill top pedon P_1 [12.90 C mol (p^+) kg^{-1}]. While in soils of Malwa plateau, cation exchange capacity was found to vary from 15.08 to 39.23 C mol (p^+) $kg^{1}$with weighted mean value of 26.06 C mol (p^+) kg^{-1}. The soils of plain (P_8) have maximum value of cation exchange capacity followed by the soils of Pedimant (P_6). While the soils of hill top (P_5) have the lowest value of CEC. A critical examination of data indicated that the cation exchange capacity of soils was found to be closely related to the clay content. The drifting of clay along with the bases down the slope might be the factor for the increased level of cation exchange capacity in subsurface layer of soils (Bhatia et al., 2005; Maji et al., 2005). It can be inferred that increase in clay content provide more exchange sites to get the cations adsorbed on it.

Base saturation

The data on per cent base saturation are presented in Table 7 Base saturation is by and large uniform in the soils of transect under study. It was found to range from 84.40 to 97.95% with a weighted mean value of 93.58% in soils of Aravali mountain ranges. While in soils of Malwa plateau it was found to range from 89.94 to 97.40% with a weighted mean value 93.92%. The higher base saturation in the soils of the study area could be attributed to the basic nature of the parent materials and also to the semi arid climatic conditions which allows bases to accumulate in soil matrix. It was uniform in all the soils of the area irrespective of the landforms.

Exchangeable sodium percentage (ESP)

Sodium saturation in the soils is expressed as ESP in the soil solution, because of its significance in deteriorating physico-chemical properties of soil and adversely

Table 7. Chemical properties: Exchangeable cations, base saturation, ESP and CEC.

Pedons	Horizon designation	Exchangeable cations (C mol (p$^+$) kg^{-1})				Base saturation (%)	ESP (%)	CEC C mol (p$^+$) kg^{-1}
		Ca^{++}	Mg^{++}	Na$^+$	K$^+$			
		I Aravali Mountain Ranges						
		Hill (Dipora)						
P1	Al	5.86	4.08	0.55	0.84	93.60	4.26	12.90
		Pediments (Lodiya)						
P2	Wt. mean	12.22	7.17	0.49	0.73	95.01	2.39	21.02
		Valley (Bhagadera)						
P3	Wt. mean	11.66	5.85	0.62	0.51	94.00	3.10	19.24
		Plain (Charpotiya)						
P4	Wt. mean	20.87	11.27	0.77	0.80	91.73	2.08	36.60
		II Malwa plateau						
		Hill (Chiklad)						
P5	Wt. mean	8.93	7.06	0.82	0.96	93.30	4.58	18.22
		Pediments (Shah ji ka pathar)						
P6	Wt. mean	19.38	8.68	1.29	1.06	96.84	4.31	26.59
		Valley (Ghotarsi)						
P7	Wt. mean	13.14	7.28	0.46	0.65	94.21	2.05	22.65
		Plain (Kuni)						
P8	Wt. mean	22.47	11.49	0.63	0.70	91.36	1.69	36.81

affecting the growth of plant. The values of exchangeable sodium percentage ranges between 1.47 to 4.30% with a weighted mean value of 2.95% in soils of Aravali mountain ranges. The highest value of exchangeable sodium percentage was found in the soils of hill top P_1 (4.26%) followed by valley soils (3.10%) while the lowest value of exchangeable sodium percentage was recorded in plain P_4 (2.08%) and in pediments (2.39%) exhibit intermediate pattern with respect to exchangeable sodium percentage. In case of soils of Malwa plateau, exchangeable sodium percentage ranges between 0.88 to 5.65% with a weighted mean value 3.1%. The soils of Malwa plateau followed the similar pattern of distribution of exchangeable sodium in all topographic positions as in the soils of Aravali mountain ranges. Highest value of exchangeable sodium percentage is observed in soils of hill top pedon P_5 (4.58%) followed by pediment soils P_6 (4.31%). While lowest value of exchangeable sodium percentage observed in soils of plain P_8 (1.69%). The variation in exchangeable sodium percentage in surface soil with respect to slope was similar to exchangeable sodium. Generally, its content was less than 5.17 percent in all the pedons. Similar results were also reported by Saxena and Singh (1982).

SOIL CLASSIFICATION

The key diagnostic properties used for the classification of soils of both transects are listed in the Tables 8 and 9 at the different categorical levels and briefly described prior the taxonomic description of the soils. The classification of the soils up to the family level is elucidated in the Table 9. The brief description about the classification is given in diagnostic characteristics

Diagnostic characteristics

The following diagnostic characteristic are used in the classification of soil in both transects under investigation.

Cambic horizons

The improvement in soil structure in terms of angularity

Table 8. Diagnostic criteria for soil classifications.

Pedons	Order	Suborder	Great group	Subgroup	Family*
P_1	No horizon development	Other entisols	Ustic moisture regime	Lithic contact depth < 50 cm	Coarse loamy skeletal mixed hyper thermic
P_2	No horizon development	Other entisols	Ustic moisture regime	Lithic contact depth < 50 cm	Loamy skeletal mixed hyper thermic
P_3	Cambic horizon	Other ustepts	Ustic moisture regime	Meets the central concept of great group	Fine loamy mixed hyper thermic
P_4	Cambic horizon	Other ustepts	Ustic moisture regime	Meet the central concept of great group	Fine calcareous hyper thermic
P_5	No horizon development	Other entisols	Ustic moisture regime	Lithic contact depth < 50 cm	Loamy mixed hyper thermic
P_6	No horizon development	Other entisols	Ustic moisture regime	Lithic contact depth < 50 cm	Fine loamy calcareous mixed hyper thermic
P_7	Cambic horizon	Other ustepts	Ustic moisture regime	Meet the central concept of great group	Fine loamy calcareous mixed hyper thermic
P_8	Intersecting slikensides cracks >40 cm deep	Other usterts	Ustic moisture regime	Meets the central concept of great group	Fine calcareous mixed hyper thermic

*Mixed mineralogy and hyper thermic temperature regime considered for all soils to classify at family level.

Table 9. Soil classification.

Pedons	Order	Suborder	Great group	Subgroup	Family*
P_1	Entisols	Orthents	Ustorthents	Lithic ustorthents	Coarse loamy skeletal mixed hyper thermic
P_2	Entisols	Orthents	Ustorthents	Lithic ustorthents	Loamy skeletal mixed hyper thermic
P_3	Inceptisols	Ustepts	Haplustepts	Typic haplustepts	Fine loamy mixed hyper thermic
P_4	Inceptisols	Ustepts	Haplustepts	Typic haplustepts	Fine calcareous hyper thermic
P_5	Entisols	Orthents	Ustorthents	Lithic ustothents	Loamy mixed hyper thermic
P_6	Entisols	Orthents	Ustorthents	Lithic ustothents	Fine loamy calcareous mixed hyper thermic
P_7	Inceptisols	Ustepts	Haplustepts	Typic haplustepts	Fine loamy calcareous mixed hyper thermic
P_8	Vertisols	Usterts	Haplusterts	Typic haplusterts	Fine mixed calcareous hyper thermic

*Content in the last column is prefixed to the name of subgroup for complete name of soil.

and grade in the subsurface horizon and/or richer in organic carbon and clay and darker in chroma and value as compared to the overlying or underlying horizons characterized the presence of cambic horizon in soils of valley (P_3) and plain (P_4) in case of Aravali mountain ranges soils while in case of Malwa plateau it was found in the soils of valley (P_7) pedons. The presence of cambic horizon is used as a diagnostic characteristic to separate the soils of inceptisols from Entisols after giving the due weight age to other features essentially needed for the other orders.

Slickensides

A layer of 25 cm or more thick with an upper boundary within 100 cm of the mineral soil surface that has either slickensides close to intersect or wedge shaped aggregates, which have their long axis tilted 10 to 60° from horizontal. This is one of the chief diagnostic characteristic required to mark a soil in Vertisols. In the present investigation, soils of pedon P_8 (plain) have more than 25 cm thick horizon within 100 cm of the surface, which have the above mentioned characteristics.

Soil moisture regime

The soils of both transects throughout the moisture control section remain dry for more than 90 days during the year and therefore quality for ustic soil moisture regime. The criterion was used as differential

Strip I	
Aravali mountain ranges	SRM Unit
P1 Dipora	172
P2 Lodiya	193
P3 Bhagadera	239
P4 Charpotiya	229

Strip II	
Malwa plateau	SRM Unit
P5 Chiklad	318
P6 Shah ji ka pathar	330
P7 Ghotarsi	324
P8 Kuni	337

Figure 1. Site for profile examination and sampling in aravali mountain ranges and malwa plateau.

characteristics for classifying the soils at the suborder level within soil great group level (Table 8).

Lithic contacts

The presence of rock within 50 cm from the surface in the soil profile is characterized as lithic contacts in the soils of hill (P_1), pediments (P_2) of Aravali mountain ranges and in soils of hill (P_5) and pediment (P_6) of the Malwa plateau (Figure 1). The criteria is used to classify the soils of both transects at subgroup level for separating the soil bearing this trait from their typic counter part.

Soil temperature regime

The soil temperature was more than 20°C within the control section and therefore qualifies for hyper thermic soil temperature regime. The difference between MWST and MSST is greater than 5°C and therefore does not qualify for isohyperthermic soil temperature regime. The criteria are used to classify the soils at the family level.

Particle size class

Coarse loamy skeletal, loamy skeletal, fine loamy, fine loamy mixed calcareous, calcareous, particle size (Table 9) characterized the soils of both transects. These together with soil temperature regime are used to classify the soils of both transect at the family level.

Depth, texture and coarse fragments

The characteristics of the soils are not directly visible in the classification. However, these together constitute the particle size class of the soils.

Taxonomic descriptions

The taxonomic classification of the soils of Pratapgarh district has been worked out based on morphological, physical and physico-chemical properties and climatic data according to Soil Taxonomy (Soil Survey Staff, 2000) into the order Entisols (Pedons P_1 and P_2 of Aravali mountain ranges and pedon P_5 and P_6 of Malwa plateau), Inceptisols (Pedons P_3 and P_4 of Aravali mountain ranges and Pedons P_7 of Malwa plateau) and Vertisols (Pedon P_8 of Malwa plateau).

No diagnostic horizon and decrease in organic carbon was observed in the soils of hill (P_1) and pediment (P_2) of the Aravali mountain ranges and in the soils of hill (P_5) and (P_6) of the Malwa plateau. While cambic horizon is a key characteristics to mark as alteration in the original parent material in soils of valley (P_3), plain (P_4) of the Aravali mountain ranges and in the soils of valley (P_7) of the Malwa plateau. Slickenside was the important feature in the soil of plain (P_8) of the Malwa plateau. Based on these diagnostic features, soils of pedon P_1, P_2, and P_5 were classified in Entisols soil order, while the soils of pedon $P_{3,}$ P_4, and P_7, were put under Inceptisols soil order. The soils of pedon P_8 was classified in Vertisol soil order.

The soil orders are further taken down to the suborder level, using the other differential characteristics. Since the soils of P_1, P_2 and $P_{5,}$ P_6 could not qualify for psamments and fluents suborder, consequently placed in orthents. Based on the soil moisture regime, the soils of inceptisols and vertisol soil order are classified as a member of ustepts and usterts suborder, respectively. The Ustic moisture regime is considered for bringing down the soil of orthents to the Ustorthents at great group level. Since ustepts and usterts do not qualify for any other great group within suborder, consequently, these have been placed in Haplustepts and Typic Haplusterts great group of their respective suborder.

Presence of rock within 50 cm of the soil profile was the criteria to separate the soils of pedon P_1, P_2, P_5 and P_6 from other Ustorthents to Lithic Ustorthents and Ustepts to Lithic Ustepts at the subgroup level, respectively. The soils of pedon $P_{3,}$ P_4, P_7, P_8, and P_9, represent the central concept of Haplustepts subgroup. As a result, these have been classified in Typic Haplustepts subgroup. The soils of pedon P_8 belonging to the Haplusterts great group also represent the central concept, consequently qualify for Typic Haplusterts subgroup of vertisols soil order.

Based on the particle size class, hyperthermic soil temperature regime, mixed mineralogy class, soils of both transects are further taken down to the lowest taxa of soil taxonomy, soil family. According these features, soils of pedon P_1 and P_2 have been classified as a member of loamy skeletal mixed hyper thermic family of Lithic Ustorthents subgroup under Entisols soil order. While soils of P_5 has been classified as a member of fine loamy mixed hyperthermic family of Typic Ustorthents subgroup. The soils of pedons P_6 in Lithic Haplustepts subgroup are classified as a member of fine loamy calcareous mixed hyper thermic soil family of Entisols soil order. In case of Pedon P_3 and P_9 soils have been classified as a member of fine loamy hyper thermic family of Typic Haplustepts in Inceptisols order. While the soils of Pedon P_4, have been classified as a member of fine loamy calcareous hyper thermic family of Typic Haplustepts in Inceptisols order. Soils of Pedon P_8 have classified as a fine mixed calcareous hyperthermic family of Typic Haplusterts subgroup of Vertisols soil order.

Conflict of Interest

The authors have not declared any conflict of interest.

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academicJournals

Vol. 10(25), pp. 2532-2536, 18 June, 2015
DOI: 10.5897/AJAR2014.9029
Article Number: 3023D2E53519
ISSN 1991-637X

http://www.academicjournals.org/AJAR

African Journal of Agricultural Research

Full Length Research Paper

Influence of NPK on crop performance and leaf nutrient status of banana under sub surface drip fertigation system

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Received 25 July, 2014; Accepted 20 May, 2015

Field experiment was carried out at AICRP- Water Management block, Agricultural College and Research Institute, Madurai during 2010 - 2011. The experiment was laid out in Randomized Block Design (RBD) with three replications. The treatments consisted of T_1-Surface irrigation with soil application of recommended dose of fertilizers, T_2- Subsurface drip fertigation of 100% RDF (P as basal, N and K through drip as urea and white potash), T_3- Subsurface drip fertigation of 100% RDF as WSF (WSF - Urea, 13: 40: 13, KNO_3), T_4- Subsurface drip fertigation of 100% RDF (50% P and K as basal, remaining N, P and K as WSF), T_5- Subsurface drip fertigation of 75% RDF (P as basal, N and K through drip as urea and white potash) + LBF, T_{6-} Subsurface drip fertigation of 75% RDF as WSF (WSF – Urea, 13: 40: 13, KNO_3) + LBF, T_7- Subsurface drip fertigation of 75 per cent RDF (50% P and K as basal, remaining N, P and K as WSF) + LBF, T_8- Subsurface drip fertigation of 100% RDF (P as basal, N and K through drip as urea and white potash)+LBF, T_9- Subsurface drip fertigation of 100% RDF as WSF (WSF - Urea, 13: 40: 13, KNO_3)+ LBF, T_{10}- Subsurface drip fertigation of 100% RDF (50% P and K as basal, remaining N, P and K as WSF)+LBF and T_{11}-Subsurface drip irrigation with LBF alone (no inorganic). Banana cv. Rasthali was used as test crop. Subsurface drip irrigation was scheduled at 100% PE once in three days and fertigation was given once in six days starting from 15 days after planting to 300 days after planting. For surface method, irrigation was scheduled at 5.0 cm depth with IW / CPE ratio of 0.8. Estimates of total water use, soil available nutrients, nutrient mobility in soil and economic returns were also recorded. Banana leaf samples should normally be taken either just before or following floral emergence and when all female hands are visible. However, the age of the tissue to be sampled depends on the nutrients being diagnosed. In most banana producing countries, the laminar structure of third leaf is sampled for tissue analysis. However samples of the central vein of third leaf and the petiole of seventh leaf are also used. The laminar structure of third leaf is sampled by removing a strip of tissue 10 cm wide, on both side of the central vein and discarding everything but the tissue that extends from the centrals vein to the centre of the lamina.

Key words: Banana, leaf analysis, nitrogen, phosphorus, potassium.

INTRODUCTION

Plant analysis has been considered a very practical approach for diagnosing nutritional disorders and formulating fertilizer recommendations (Kelling et al., 2000). Plant analysis, in conjunction with soil testing, becomes a highly useful tool not only in diagnosing the nutritional status but also an aid in management decisions for improving the crop nutrition (Rashid, 2005). Plant analysis is the quantitative analysis of the total nutrient content in a plant tissue, based on the principle that the amount of a nutrient in diagnostic plant parts indicates the soil ability to supply that nutrient and is directly related to the available nutrient status in the soil (Malavolta, 1994; Havlin et al., 2004). It is a very practical and useful technique for fruit trees and long duration crops (Rashid, 2005). Hence, it seems quite convenient and appealing for bananas also.

Bananas are heavy feeder of nutrients (Jones, 1998) and thus need to balanced nutrition for optimum growth and fruit production, and in turn potential yields. A deficiency or excess of nutrients can cause substantial damage to the plant (Memon et al., 2001). The early (until the mid-1960s) researches on banana nutrition had concentrated on the description of symptoms of nutrient imbalance and the conduct of field experiments comparing response to rates of applied fertilizer on a range of soil types. During last three decades, scientists attempted to understand more clearly the role of nutrients in the growth and development of bananas. Field studies of fertilizer response are still being conducted, but attempts to relate nutrient concentrations in the soil and plant to yield have complemented this work.

MATERIALS AND METHODS

The experiment was laid out in Randomized Block Design (RBD) with three replications. The treatments consisted of T_1-Surface irrigation with soil application of recommended dose of fertilizers, T_2- Subsurface drip fertigation of 100% recommended dose of fertilizer RDF (P as basal, N and K through drip from the source of urea and white potash), T_3- Subsurface drip fertigation of 100% RDF by Water Soluble Fertilizer (WSF – Urea, 13: 40: 13, Pottasium nitrate (KNO_3), T_4- Subsurface drip fertigation of 100% RDF (50% P and K as basal, remaining N, P and K through WSF), T_5- Subsurface drip fertigation of 75% RDF (P as basal, N and K through drip from and white potash) + LBF, T_6- Subsurface drip fertigation of 75% RDF as WSF (WSF - Urea, 13: 40: 13, KNO_3) + Liquid Bio Fertilizer (LBF), T_7- Subsurface drip fertigation of 75 per cent RDF (50% P and K as basal, remaining N, P and K by WSF) + LBF, T_8- Subsurface drip fertigation of 100% RDF (P as basal, N and K through drip from urea and white potash) +LBF, T_9- Subsurface drip fertigation of 100% RDF as WSF (WSF - Urea, 13: 40: 13, KNO_3) + LBF, T_{10}- Subsurface drip fertigation of 100% RDF (50% P and K as basal, remaining N, P and K by WSF) + LBF and T_{11}-Subsurface drip irrigation with LBF alone (no inorganic).

The leaf samples were taken from the third upper leaf from the top of the plant at different growth stages by Mitra and Dhue (1988). Ten plants were selected at random and the samples of the index tissue comprising 10 cm wide stripes of leaf blade in the centre of the leaf and on either side of the mid rib were collected from recently matured leaf. A composite sample was prepared for by combining the leaf stripes obtained from 10 plants for each treatment. Decontamination of samples was done by washing them with distilled water (Chapman and Parker, 1961). The samples were dried in shade and then in air oven at 60°C and were ground in a Willey mill using stainless steel grinder and stored in labeled container for the analysis of total N, P and K by following the procedures. Total nitrogen analyzed by micro kjeldahl distillation method by Humphries (1956). Total Phosphorus by Vanadomolybdate colour method of Jackson (1973) and Total Potassium by Flame photometry in triple acid extract of Piper (1966).

RESULTS AND DISCUSSION

Leaf nutrient concentration

Effect of subsurface drip fertigation on leaf N content (percent)

The leaf N steadily increased from 3 MAP to shooting stage and thereafter it decreased. At 3 MAP, subsurface drip fertigation of 100% RDF as WSF (WSF - Urea, 13: 40: 13, KNO_3) + LBF (T_9) recorded the highest leaf N content of 2.97%. This treatment was on par with subsurface drip fertigation of 100% RDF (50% P and K as basal, remaining N, P and K as WSF) +LBF (T_{10}) and subsurface drip fertigation of 100% RDF (P as basal, N and K through drip as urea and white potash) + LBF (T_8). The treatment subsurface drip irrigation with LBF alone (No inorganic) (T_{11}) recorded the lowest leaf N content.

At 5 MAP, subsurface drip fertigation of 100% RDF as WSF (WSF - Urea, 13: 40: 13, KNO_3) + LBF (T_9) ranked best by registering higher leaf N content of 3.42%. The lowest leaf N content was recorded in the treatment subsurface drip irrigation with LBF alone (No inorganic) (T_{11}).

At shooting stage, subsurface drip fertigation of 100% RDF as WSF (WSF - Urea, 13: 40: 13, KNO_3) + LBF (T_9) recorded the highest leaf N content of 3.99% which was on par with subsurface drip fertigation of 100% RDF as WSF (WSF - Urea, 13: 40: 13, KNO_3) (T_3). The treatment LBF subsurface drip irrigation with alone (No inorganic) (T_{11}) recorded the lowest leaf N content.

At harvesting stage, subsurface drip fertigation of 100% RDF as WSF (WSF - Urea, 13: 40: 13, KNO_3) (T_3) was found to maintain higher leaf N content of 3.62%. This treatment was on par with subsurface drip fertigation of 100% RDF as WSF (WSF - Urea, 13: 40: 13, KNO_3) + LBF (T_9), subsurface drip fertigation of 100% RDF (50% P and K as basal, remaining N, P and K as WSF) +LBF (T_{10}) and subsurface drip fertigation of 100% RDF (P as basal, N and K through drip as urea and white potash) +

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Table 1. Effect of subsurface drip fertigation levels on leaf N content (per cent) of banana.

Treatment	3 MAP	5 MAP	At harvest
T_1	2.43	3.16	3.01
T_2	2.40	2.73	3.15
T_3	2.74	3.17	3.62
T_4	2.70	3.05	3.18
T_5	2.65	3.19	3.13
T_6	2.75	3.11	3.26
T_7	2.41	3.15	3.31
T_8	2.85	2.83	3.47
T_9	2.97	3.42	3.58
T_{10}	2.85	3.20	3.43
T_{11}	2.30	2.71	3.20
SE d	**0.06**	**0.09**	**0.13**
CD(P=0.05)	**0.14**	**0.20**	**0.27**

MAP, Months after planting.

Table 2. Effect of subsurface drip fertigation levels on leaf P content (per cent) of banana.

Treatment	3 MAP	5 MAP	At harvest
T_1	0.24	0.28	0.23
T_2	0.26	0.28	0.25
T_3	0.21	0.29	0.24
T_4	0.29	0.31	0.23
T_5	0.31	0.30	0.22
T_6	0.27	0.28	0.23
T_7	0.25	0.26	0.20
T_8	0.28	0.29	0.22
T_9	0.30	0.31	0.23
T_{10}	0.28	0.30	0.24
T_{11}	0.20	0.22	0.21
SE d	**0.01**	**0.01**	**NS**
CD(P=0.05)	**0.02**	**0.02**	

MAP, Months after planting.

LBF (T_8). The lowest leaf N content was record in surface irrigation with soil application of RDF (T_1) (Table 1).

Effect of subsurface drip fertigation on leaf P content (percent)

At 3 MAP, higher P content (0.31%) was observed under subsurface drip fertigation of 75% RDF + LBF (P as basal, N and K through drip as urea and white potash) (T_5) which was on par with subsurface drip fertigation of 100% RDF as WSF (WSF - Urea, 13: 40: 13, KNO_3) + LBF (T_9) and subsurface drip fertigation of 100% RDF (50% P and K as basal, remaining N, P and K as WSF) (T_4).

The lowest leaf P content was recorded in the treatment subsurface drip irrigation with LBF alone (No inorganic) (T_{11}). At 5 MAP, subsurface drip fertigation 100 per cent RDF as WSF (WSF - Urea, 13: 40: 13, KNO_3) + LBF (T_9) and subsurface drip fertigation of 100% RDF (50% P and K as basal, remaining N, P and K as WSF) (T_4) were comparable and recorded the highest leaf P content of 0.31%. These treatments were closely followed by subsurface drip fertigation of 100% RDF (50% P and K as basal, remaining N, P and K as WSF) + LBF (T_{10}) and subsurface drip fertigation of 100% RDF as WSF (WSF - Urea, 13: 40: 13, KNO_3) (T_3). The lowest leaf P content was recorded in the treatment subsurface drip irrigation with LBF alone (No inorganic) (T_{11}).

At shooting stage, subsurface drip fertigation of 100% RDF as WSF (WSF - Urea, 13: 40: 13, KNO_3) + LBF (T_9) recorded the higher leaf P content of 0.33. This treatment was on par with subsurface drip fertigation of 100% RDF as WSF (WSF - Urea, 13: 40: 13, KNO_3) (T_3) and subsurface drip fertigation of 100% RDF (50% P and K as basal, remaining N, P and K as WSF) + LBF (T_{10}). The lowest leaf P content was recorded in the treatment subsurface drip irrigation with LBF alone (No inorganic) (T_{11}).

The leaf P content at harvesting stage was not significantly by fertigation treatments (Table 2).

Effect of subsurface drip fertigation on leaf K content (percent)

At 3 MAP, the highest leaf K content (3.46%) was recorded in subsurface drip fertigation of 100% RDF as WSF (WSF - Urea, 13: 40: 13, KNO_3) + LBF (T_9) and it had similar effect with subsurface drip fertigation of 100% RDF (50% P and K as basal, remaining N, P and K as WSF) (T_{10}). The lowest leaf K content was observed in surface irrigation with soil application of RDF (T_1).

As the crop stage advanced from 5 MAP to shooting, subsurface drip fertigation of 100% RDF as WSF (WSF - Urea, 13: 40: 13, KNO_3) + LBF (T_9) showed its superiority by registering the highest leaf K content. The treatment subsurface drip irrigation with LBF alone (No inorganic) (T_{11}) recorded the lowest leaf K content.

At harvesting stage, subsurface drip fertigation of 100% RDF as WSF (WSF - Urea, 13: 40: 13, KNO_3) + LBF (T_9) maintained the highest leaf K content (3.61%). This treatment was on par with subsurface drip fertigation of 100% RDF (50% P and K as basal, remaining N, P and K as WSF) +LBF (T_{10}), subsurface drip fertigation of 75% RDF + LBF (P as basal, N and K through drip as urea and white potash) (T_5) and subsurface drip fertigation of 100% RDF (50% P and K as basal, remaining N, P and K

Table 3. Effect of subsurface drip fertigation levels on leaf K content (per cent) of banana.

Treatment	3 MAP	5 MAP	At Harvest
T_1	2.19	2.83	2.95
T_2	2.93	2.88	3.18
T_3	3.15	3.48	3.31
T_4	3.04	3.65	3.48
T_5	3.02	3.53	3.41
T_6	2.64	3.33	3.40
T_7	2.98	3.17	3.32
T_8	2.95	3.40	3.21
T_9	3.46	3.91	3.61
T_{10}	3.33	3.69	3.45
T_{11}	2.45	2.39	3.11
SE d	**0.09**	**0.09**	**0.10**
CD(P=0.05)	**0.19**	**0.20**	**0.21**

MAP, Months after planting.

as WSF) (T_4). The lowest leaf K content was noted in surface irrigation with soil application of RDF (T_1) (Table 3).

DISCUSSION

The leaf NPK was affected significantly by subsurface drip fertigation treatments under this investigation. The highest NPK percentage in leaf was recorded by plants received subsurface drip fertigation of 100% RDF as WSF (WSF - Urea, 13: 40: 13, KNO_3) + LBF. In general, there was an increase in NPK contents in all the treatments up to shooting and thereafter the values declined. This shows a heavy loading of NPK in leaves during vegetative and shooting stage followed by a decrease in the concentration due to rapid increase in dry matter caused by faster growth of banana crop. Mitra and Dhue (1988) reported a continuous uptake of N up to shooting in banana. Ram and Prasad (1985) observed an increase in the content of N up to flowering in banana.

It was further observed that the content of NPK was always higher when drip fertigation is integrated with liquid bio fertilizers. Application of nutrients at six interval up to 300 days maintained the NPK content of the third youngest leaf always at a higher level, when compared to surface irrigation with soil application of recommended dose of fertilizers. This indicates that nutrients are more efficiently absorbed and distributed within the plant when the frequency of application increases. Therefore, more frequent application of NPK could be beneficial for growing banana. However, at the other stages of growth, the NPK content in leaf should be maintained at 3.0% for N, 0.30% for P and 3.50% for K. Different workers have proposed different critical levels of nutrients in third leaf of banana which range from 1.80 to 4.0% for N (Angeles et al., 1993), 0.17 to 0.29% for P (Lahav and Turner, 1983) and 1.66 to 5.40% for K (Noor-Un-Nisha Memon et al., 2010).

Conclusion

Plant analysis is on authoritative tool for evaluating nutrient deficiency, toxicities and imbalances, identifying hidden hunger, deciding fertilization plants, studying nutrient interaction and determining the availability of element for which reliable soil tests have not been developed. The highest NPK content at shooting stage was recorded in plants received subsurface drip fertigation of 100% RDF as WSF (WSF - Urea, 13: 40: 13, KNO_3) + LBF (T_9). This was followed by subsurface drip fertigation of 100% RDF as WSF (WSF - Urea, 13: 40: 13, KNO_3) (T_3), subsurface drip fertigation of 100% RDF (50% P and K as basal, remaining N, P and K as WSF) + LBF (T_{10}) and subsurface drip fertigation of 100% RDF (P as basal, N and K through drip as urea and white potash) + LBF (T_8). The treatment subsurface drip irrigation with LBF alone (no inorganic) (T_{11}) recorded the lowest NPK content in leaves.

Conflict of Interest

The authors have not declared any conflict of interest.

ACKNOWLEDGMENT

The authors express sincere thanks and gratitude to International Panaacea Ltd., New Delhi for financial support in sponsoring the research project.

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academicJournals

Vol. 10(25), pp. 2537-2543, 18 June, 2015
DOI: 10.5897/AJAR2015.9771
Article Number: AB0CA4953521
ISSN 1991-637X

http://www.academicjournals.org/AJAR

African Journal of Agricultural Research

Full Length Research Paper

Yield and oil content of peanut (var. TMV-7) and sunflower (var. Co-2) applied with bio-stimulant AQUASAP manufactured from seaweed

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Received 30 March, 2015; Accepted 26 April, 2015

The effect of bio-stimulant AQUASAP manufactured from seaweed *Kappaphycus alvarezii* (Rhodophyta) farmed in Indian water on the yield and oil content of peanut and sunflower was studied under field condition. The AQUASAP at 5% foliar application promoted the vegetative growth, yield and oil content in both peanut and sunflower significantly. Compared to control the yield of seed in peanut increased by 31.69% with 14.27% more oil content similarly on sunflower the increase in seed yield and oil content were 51.50 and 15.77% respectively. Therefore, the bio-stimulant AQUASAP can be applied on oil crops like peanut and sunflower to improve the yield and quality of crop and therefore, it has huge potential to contribute to organic agriculture in future.

Key words: AQUASAP, bio-stimulant, plant nutrient, seaweed, *Kappaphycus alvarezii*, peanut, sunflower, yield and oil content.

INTRODUCTION

The coastal ecosystems provide habitat to genetically, ecologically and economically valuable biological organisms. Seaweeds contain all the trace elements and plant growth hormones required by plant to enhance yield attributes (Latique et al., 2013). Seaweed liquid fertilizer contains micro and macro nutrient and growth promoters (Prasad et al., 2010). Seaweed extract or juice or suspension is used in agriculture and horticulture land for economical valuable. Kamaladhasan and Subramanian (2009) had reported that the seaweed extracts derived from *Sargassum wightii* (Ochrophyta, Phaeophyceae), *Gracilaria corticata* (Rhodophyta) and *Caulerpa scalpelliformis* (Chlorophyta) were effective in increasing the growth parameters. Some commercial seaweed based plant nutrients available in market are Maxicrop, Algifert, Goenar, Kelpak, Seaspray, Seasol, SM3, Cyctex and Seacrop. Seaweed bio-fertilizers are better than other fertilizers and very economical (Pise and Sabale, 2010). Effect of seaweed extracts have been studied on different range of agriculture and horticulture plants (Abetz, 1980; Crouch and Van Staden., 1990; Sridhar and Rengasamy, 2011) and found improved crop yield.

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Abbreviation: **SLF**, Seaweed liquid fertilizers; **Avg**, Average.

Increase in yield of several crops like *Capsicum annuum*, black gram, and canola plant (*Brassica napus*) were reported with foliar application of extract from seaweed *Kappaphycus alvarezii* (Zodape et al., 2010). Recently Karthikeyan and Shanmugam (2014) have observed the significant improvement in the yield and quality of some banana varieties applied with bio-stimulant Aquasap.

Groundnut is rich in oil, protein and high energy value and it is important in vegetarian diets. Groundnut is one of the major oilseeds of India. Total world production of groundnut in 2013-2014 was approximately 39.34 million tonnes. In India, groundnut production in Kharif (2012-2013) was 26.20 lakh tonnes and 47.15 lakh tonnes in Kharif 2013 to 2014 and in Tamil Nadu, during Kharif 2013-2014 it was about 1.80 lakh tonnes (TNAU, internet-1, 2014). The Seaweed Liquid Fertilizer (SLF) of *Hypnea musciformis* (Rhodophyta) could be used as foliar spray at low concentration of 2% to maximize the growth and yield of *Arachis hypogaea* and also increase the number of stomata in the yield (Ganapathy-selvam and Sivakumar, 2014). Babu and Rengasamy (2012) had recorded the maximum yield of groundnut of 170.6 g/pot treated with 1% SLF of *K. alvarezii* followed by 158.3 g/pot (2% treated) in the plants which were more than 30.6 and 21.2% respectively when compared to agriculture control (130.6 g/pot).

Sunflower is another important oilseed crops in India and it's occupied in fourth place of acreage and production. The presence of oil in sunflower is higher (45 to 50%) over other oil seed crop and the sunflower cake makes high quality cattle and poultry feed because of higher protein (40 to 44%) and balanced amino acid contents. Total world production of sunflower seeds in 2013 to 2014 was about 42 million tonnes and it was 36.40 million tonnes during 2012 to 2013. In India, sunflower seed production in kharif (2013 to 2014) was 1.85 lakh tonnes and the same was 1.50 lakh tonnes in Kharif 2012-2013. In Tamil Nadu the sunflower seed production was around 24,622 T for an area of 13,610 ha during 2011-2012 (TNAU, internet-2, 2014).

The bio-stimulant AQUASAP extracted from seaweed *K. alvarezii* is rich in potash (K) with other primary and secondary nutrients, additionally it contains substantial amount of plant growth regulators such as auxin, cytokinin and gibberellins (Prasad et al., 2010). The present investigation describes the stimulation effect of AQUASAP on the yield and oil content of peanut and sunflower for the first time.

MATERIALS AND METHODS

Seeds of groundnut (var. TMV-7) and sunflower (var. CO_2) were obtained from Regional Pulses Research station, Tamil Nadu Agriculture University, Coimbatore. The seeds were stored in metal tin as suggested by Rao (1976). Experiment of peanut and sunflower were conducted in Agri R&D plot of AquAgri Processing Private Limited, Manamadurai, India (Latitude 9°42′56″N and Longitude 78° 28′2″E) in August 2012. Farmyard manure was applied at 50 T/ha basis and ploughed the trial site 3 times and soil was broken into finely soil with rotovator. The plot size made was 6 m × 4 m and experiment was conducted in 8 plots per test crop. The seeds were treated with 0.1% mercuric chloride for sterilization and then carefully sowed into the field. 300 numbers of plants were maintained in each plot and extra plants were removed by handpicking on 25th day of sowing. The test crops were irrigated on weekly intervals by sprinkling method. Commercially manufactured AQUASAP (Batch no: 21042012-2) was collected from of stock of Aquagri Processing Private Limited, Manamadurai, India and used in the present study.

The AQUASAP was applied at 5% conc. for 3 times through foliar application for peanut, first spray was given at vegetative phase (25th day of sowing), second dose was applied at pod development stage that is, 45 days after sowing and last spray was given at maturity phase (65 days). The plants of peanuts were uprooted at the harvesting time and the pods were separated by hand picking. The data on plant weight, plant height, no. of branches, seed weight, no. of seeds, fresh and dry fodder, fresh and dry pods, dry seed and dry shell were collected.

Sunflower was similarly applied with 5% AQUASAP solution for 3 times through foliar application that is, first spray was given at vegetative phase (25th day of sowing), second dose was applied at flowering stage that is, 45 days after sowing and last spray was given at maturity phase (65 days). The harvested heads sunflower was thrashed and seed were collected. The data on plant height, diameter of flower, no. of seeds per head, fresh and dry weight of seed were collected. Oil was extracted by continuous extraction in a soxhlet apparatus used hexane as solvent, as described by Jambunathan et al. (1985).

Statistical analysis

Statistical analysis such as analysis of variance (ANOVA, SYSTAT version 7), correlation and regression were applied to analysis the data.

RESULTS

Peanut

In peanut 10 plants were taken randomly in each plot of control and AQUASAP treated and measured the height, no. of branches and no. of seeds. Height of control plant ranged from 75 to 99 cm with an average of 84.5 cm and it was 104 to 120 cm (avg. 110.9 cm) in 5% AQUASAP treated plants; therefore 31.24% more yield over control with significant positive correlation (r=0.530; p= 0.1) was observed. Average (avg) no. of branches in control and treated plants were 6.6 nos. (4 to 10 nos.) and 8.1 nos. (5 to 15 nos.) respectively but not significantly correlated with control (Table 1).

The reading taken from 4 plots are given as follows. Weight of fresh fodder of control plant per plot ranged from 125 to 190 kg with average 159.9 kg whereas in treated plants it was and 162 to 219 kg (avg 192.8 kg) that is, 20.58% more weight was obtained in treated plants (r=0.524; p=0.1). Average dry fodder in control and treated plants were 88.3 kg (49-193 kg) and 108 kg (75-174 kg) respectively (r=0.624; p= 0.05) that is, dry fodder increased to 22.31% as compared with control

Table 1. Vegetative growth, yield and oil content of peanut applied with bio-stimulant AQUASAP.

Characters	Control	Yield of 5% AQUASAP treated plants	% of yield increase in treated plants
Plant height (cm)	84.5±6.45	110.9±5.72	31.24
No. of branches (no.)	6.6±1.62	8.1±3.69	22.72
No. of seeds (no.)	14.2±2.96	18.7±1.55	31.29
Fodder fresh wt/ plot *4 (kg)	159.9±17.77	192.8±19.01	20.58
Dry fodder wt/plot *4 (kg)	88.3±42.03	108±41.82	22.31
Fresh pods wt/plot *4 (kg)	84±8.84	112.4±17.51	33.81
Dry pods wt/plot *4(kg)	37.9±7.65	44.9±5.07	18.40
Dry seeds wt/plot *4 (kg)	14.2±2.96	18.7±1.55	31.69
Dry shells wt/plot *4 (kg)	19.8±2.89	27.4±3.55	38.38
Oil content (%)	47.16±2.63	53.89±2.73	14.27
Dry seed / ha (kg)	1479.00	1947.00	31.69
Oil content / ha (ltr)	697.40	1049.20	14.27

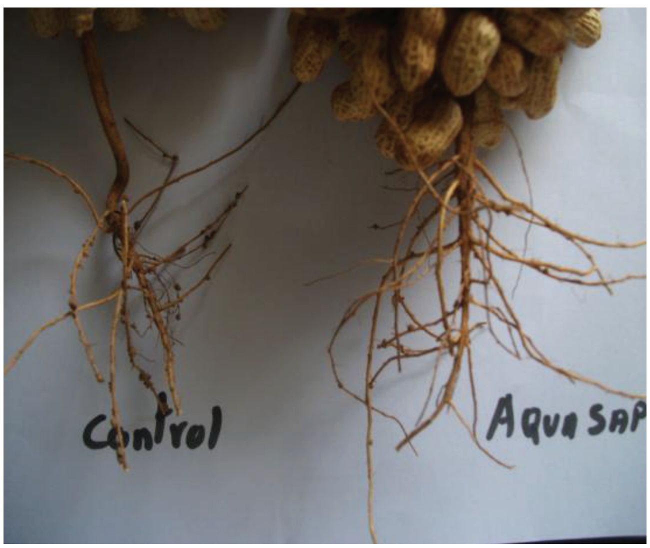

Figure 1. Root system of peanut – more no. of lateral branches with nodes in treated plant.

(Table 1).

First flower was observed on 35th day of plantation in treated plant and same was observed on 47th day in the case on control plants. Maximum flower was observed after 8th weeks of plantation. The root system of 5% AQUASAP treated plants had more no. of lateral branches with nodes as compared to agriculture control (Figure 1).

Seeds of treated pods were large and more uniform in size with 94% of two seeds per pod whereas the pods of control was irregular in size, smaller and 17% pods were with single seed (Figure 2). The no. of seeds ranged from 10 to 18 nos. (avg. 14.2 nos.) and 13 to 26 nos. (avg 18.7 nos.) in control and treated plant respectively with significant positive correlated with control (r= 0.537: p=0.1) and with 31.29% increased in treated one (Table 1).

Average fresh pod weight in control and treated plants were 84 kg (72 to 97 kg) and 112.4 kg (86 to 148 kg) respectively with significant positive correlation (r= 0.774; p=0.01) and with 33.18% more yield over control. Dry pods of control ranged from 25 to 48 kg (avg 37.9 kg) and 35 to 51 kg (avg 44.9 kg) treated plants and 18.4% more yield over control respectively and significant positive correlated with control (r=0.815; p= 0.01). The oil content ranged from 43.57 to 50.48% (avg 47.16%) and 50.15 to 57.88% (avg 53.89%) in control and treated plants respectively with 14.27% more yield over control. Dry seed weight ranged from 10 to 20 kg (avg 14.2 kg) and 16 to 21 kg (avg 18.7 kg) in control and treated plants respectively with significant positive correlated with control (r=0.797; p= 0.01) that is, 31.69% more yield as compared to control. Average dry shell weight in control and treated plants were 19.8 kg (15 to 24 kg) and 27.4 kg (21 to 34 kg) respectively (r= 0.660; p= 0.05) with 38.38% more yield over control (Table 1 and Figure 3).

Sunflower

Plant height of control ranged from 120.1 to 158.2 cm (avg134.18 cm) and 120.8 to 165.7 cm (avg 148.37 cm) in 5% AQUASAP treated plants with 10.57% more yield over control (Table 2) with no significant positive correlated with control plant. The flower head diameter ranged from 10.1 to 20.5 cm (avg 14.57 cm) and 16.7 to 21.5 cm (avg 19.2 cm) in control and treated plants respectively with 31.78% increased yield in treated plants (r= 0.820; p= 0.01). The no. of seeds per head ranged from 912 to 1020 nos. (avg 964.5 nos.) and 1128 to 1180 nos. (1150.2 nos.) in control and treated plants respectively that is, 9.25% increased yield in treated plants with significant positive correlated with control

Figure 2. Quality of seeds obtained from peanut treated with 5% AQUASAP and control plant.

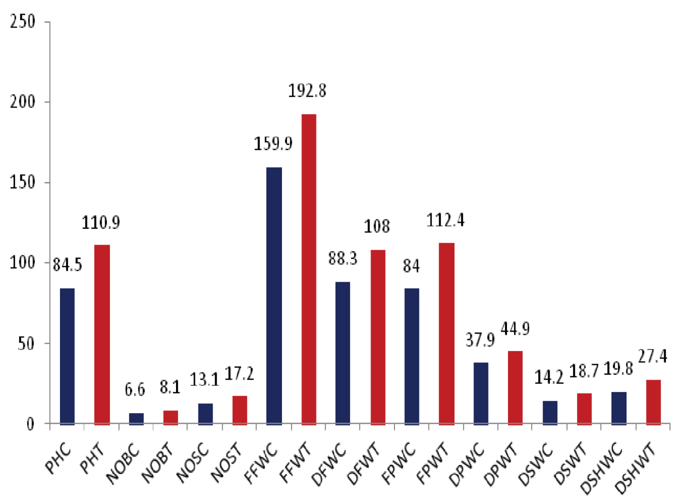

Figure 3. Vegetative growth and yield of peanut applied with bio-stimulant AQUASAP. PHC- Plant height in control, PHT – Plant height in treated, NOBC – No. of branches in control, NOBT- No. of branches in treated, NOSC – No. of seeds in control, NOST – No. of seeds in treated, FFWC-Fresh fodder weight in control, FFWT – Fresh fodder weight in treated, DFWC- Dry fodder weight in control, DFWT – Dry fodder weight in treated, FPWC- Fresh pod weight in control , FPWT – Fresh pod weight in treated, DPWC- Dry pod weight in control, DPWT – Dry pod weight in treated, DSWC – Dry seed weight in control, DSWT- Dry seed weight in treated, DSHWC – Dry Shells weight in control, DSHWT- Dry shells weight in treated.

(r=0.712; p=0.02). Average seed yield in control and treated plant were 9.98 kg (9.3 to 10.8 kg) and 15.1 kg (12.9 to 20.3 kg) respectively with 51.30% more yield over control respectively and with significant positive correlated with control (r=0.571; p=0.1). The oil content ranged from 19.37 to 32.18% (avg 27.14%) and 28.35 to 34.81% (avg 31.42%) in control and treated plants respectively with 15.77% more yield over control respectively (Table 2).

DISCUSSION

Seaweed fertilizers have often been more beneficial to the crop plants than the conventional chemical fertilizer. Seaweed meals provide nitrogen (N), phosphorous (P), potassium (K) and beside some readily available micro element to the plants (Elumalai and Rengasamy, 2012). Applying seaweed extract increases the response of different growth parameters and yield responses while the differences among hybrids remained the same (Abdel Mawgoud et al ., 2010).

The present investigation is additional evidence that seaweed extract increases the growth and production of crops. The plant height increased by 31.24 and 10.57% in treated plant of peanut and sunflower respectively. The no. of branches increased by 22.72% in treated plant of peanut. Aldworth and van Staden (1987) reported that Marigold seedling treated with seaweed concentrate were more robust and healthier in appearance than the control. Safinaz and Ragaa (2013) reported that the extract of *Laurencia obtusa*, *Jania rubens*, *Corallina elongata* (Rhodophyta) treated with Maize plant to increase the leave number and plant height. Abdel Mawgoud et al ., (2010) reported that vegetative parameters that is, plant length, number of leaves, leaf area, and number of branches and fresh weight of shoot, responded positively and significantly to the application of seaweed extract with a gradual effect relative to the applied concentration.

In the present investigation, fresh and dry fodder weights increased by 20.58 and 22.31% respectively in treated peanut plants. Balamurugan and Sasikumar (2012) have also observed similar kind of result when *Abelmoschus esculentus* raised from seed treated with 10% *Sargassum myryocystem* SLF. Kamaladhasan and Subramanian (2009) have reported the seaweed extracts derived from *Sargassum wightii* (Ochrophyta, Phaeophyceae), *Gracilaria corticata* (Rhodophyta) and *Caulerpa scalpelliformis* (Chlorophyta) were effective in increasing the growth parameters. Groundnut fodder is a good fodder and it is reported that milk production increased by 11% when it fed to cows and buffalos (New Agriculturist, Internet- 3, 2012). In sunflower, no. of loose seed observed in control was 8.5% and it was only 2.3% in the case of treated plants (Figure 4). It was also observed that roots of treated peanut grown lengthier with more nodes than control (Figure 1).

Zodape et al. (2010) had reported yield increased of 30.11% in green gram when treated with extract of *K. alvarezii*. In this present study, number of seeds in treated peanut and sunflower plants increased by 31.29 and 19.25% respectively. Pod weights of peanut plants were increased by 33.81 and 18.4% in fresh and dry

Table 2. Vegetative growth, yield and oil content of sunflower applied with bio-stimulant AQUASAP.

Characters	Control	5% AQUASAP treated	% of yield increase
Plant height (cm)	134.18±11.34	148.37±13.47	10.57
Head die (cm)	14.57±2.98	19.2±1.54	31.78
No. of seeds/ head (nos.)	964.5±42.69	1150.2±17.50	19.25
Seed yield / plot (kg)	9.98±0.49	15.1±2.36	51.30
Oil content (%)	27.14±4.54	31.42±2.08	15.77
Seed yield / ha (kg)	1039.60	1572.90	51.30
Oil content / ha (ltr)	282.10	494.20	15.77

Figure 4. Quality of seeds obtained from sunflower treated with 5% AQUASAP and control plant.

respectively and increase in dry seed and shells of peanut were 31.69 and 38.38% respectively. Peanut shells are important from nitrogen recycling point of view as it is a nitrogen rich material. Similarly, higher yields had been observed with brinjal (41.1%), wheat (42.8%), onion (22.0%) and sesamum (34.15%) when they were treated with extract of *K. alvarezii* (Eswaran et al., 2005). Seaweed extract application on plant is suggested to capable of increasing nutrient concentrations in the leaves, through involvement of growth hormone in the process of nutrients absorption and movements in a plant, thus increasing the weight of plants. Extract of seaweed *Hydroclathrus* sp. (Rhodophyta) increased the number of tiller, fresh weight of stem and root, number of panicles, number of grains, grains weight (Sunarpi et al., 2010).

Sunflower head diameter increased by 31.78% with seed yield of 51.03% in treated and control respectively. Zodape et al. (2008) have reported that length increased to 31.77 and 18.24% of diameter in okra when they were treated with extract of *K. alvarezii*. Seaweed concentration application improves the root and shoot fresh system, the number of leaves, the stem diameter and no. of flowers and flower buds produced (Aldworth and van Staden, 1987). De et al. (2013) observed that the onion applied with biozyme (*Ascophyllum nodosum,* Phaeopheceae), yielded better growth, yield and quality. Anisimov et al. (2013) have reported that the application of extract from seaweeds *Ahnfeltiopsis flabelliformis*, *Neorhodomela larix* (Rhodophyta) and *Stephanocystis crassipes* (Phaeophyceae) on buckwheat increased growth of the seedling roots in maximum by 16, 20 and 15% over control respectively.

The observation of SLF treated *Arachis hypogea* plants suggested that the growth and biochemical characteristic of pulse crop might by promoted by micro and macro elements and growth promoting hormones present in the extract of *H. musiformis* (Ganapathy-selvam and Sivakumar, 2014). Sun et al. (1997) reported the better developed root systems caused by SWC treatments may also reduce the stress on the plant delaying leaf senescence.

A. hypogaea treated with 1% SLF of *S. wightii*, *Ulva lactuca* (Chlorophyta) plus 50% recommended rate of chemical fertilizers showed an increased yield to ca. 4.1 kg fresh weight which was more than 11% to that the plants received with 100% recommended rate of chemical fertilizers (Sridhar and Rengasamy, 2010). Chouliaras et al. (2009) conducted to N and N+B treatments, the additional application of SWF (treatments N+SWF and N+B+SWF) increased productivity by 45 and 51% respectively and oil content of drupes (By 33 and 23% respectively) and accelerated maturation (colour development) of the olive fruits.

Impact of potassium

AQUASAP, bio-stimulant of *K. alvarezii* contains micro, macro nutrients and growth hormones and it is rich potash about 1.6% (Prasad et al., 2010). Potassium is a key element for the plants metabolism and contributes to the development of proteins, enzymes and vitamins as well as plant photosynthesis. Potassium plays an essential role in transport systems within the plant and it improves water use efficiency. (SOPIB report, internet-4, 2011). Potassium improves the physical quality, disease resistance, and self life of fruits and vegetables (internet-5, 1998). Peanut is a leguminous crop and it's fixed in atmospheric nitrogen in root nodules. Potassium deficiency in control plant of peanut showed plants does not grow normally and appear irregular in shape. Plant leaves a yellowish green, exhibit chlorosis, dry and scorched at the edges and the leaf surface was irregularly chlorotic.

Christin et al. (2009) had observed that potassium deficiency in sunflower plants exhibited slightly reduced plant height and leaf number but highly reduced root length. Sami Suzer (internet-6, 2010) reported potassium provides strength to plant cell walls and is involved in the lignifications of sclerenchyma tissues of sunflower plant. Potassium deficiency can be one of reasons for early lodging because of a reduced growth rate of the cambium in stem of sunflower plant. Potassium increases root growth, improves drought resistance, and it helps in photosynthesis and food formation and to protect against pests and diseases. Potassium is well known to improve resistance to a number of pests, diseases and environmental stresses in sunflower crops. Increase yield and quality improvement may be due to presence of plant growth regulators and other macro and micronutrients including potassium present in the seaweed extract AQUASAP and it could also play a role absorbing other chemical inputs applied to the plants. Karthikeyan and Shanmugam (2014) have observed that the AQUASAP on some banana varieties increased the yield with improved quality.

Control of plant disease

Seaweed extract have been reported to increase plant resistance to pests and diseases, plant growth, yield and quality (Jolivet et al., 1991; Verkleij, 1992; Pardee et al., 2004). Sultana et al. (2011) had reported several seaweed extract control of root rotting fungi like *Macrophomina phaseolina, Rhizoctonia solani, Fusarium* species and root knot nematode (*Meloidogyne* spp.,) on various crops. Ara et al. (1996) had reported carried out on the use of seaweed viz*. Sargassum* spp. (Phaeophyceae), in the control of root rot disease of sunflower plant. Zahid et al. (1999) had reported seaweed fertilizer increase the resistibility against disease and reduce the chance of insect attack.

Conclusion

It can be concluded from present study that oil varieties of peanut and sunflower had responded well to 5% AQUASAP (Brand name of AquAgri for bio-stimulant of seaweed *K. alvarezii*) with average yield increased of 31.69 and 51.30% of peanut and sunflower respectively with much improved seed quality. Commonly SLF is a powerful, alternate to synthetic fertilizer and environmental eco-friendly and its approach to improve the plant growth and yield of all crops. SLF is helping our farmer to apply balanced fertilizer application and also reduce the cost of yield production. Present findings encourage the application of such seaweed extract as bio-stimulant in agriculture sector.

Conflict of Interest

The authors have not declared any conflict of interest.

ACKNOWLEDGEMENTS

The authors are very grateful to Mr. Abhiram Seth, MD and Mr. Arun Patnaik, CEO of AquAgri Processing Private Limited for their constant encouragement and guidance to carry out the present investigation. The authors also wish to thank Mr. Tanmaye Seth and staff of AquAgri Processing Private Limited, India for their support during the study.

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