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Effect of agronomic practices on growth, dry matter and yield of Rajmash (*Phaseolus Vulgaris* L.)

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Rajmash (*Phaseolus vulgaris* L.) is an important cash crop widely grown under temperate and subtropical regions. Being a pulse crop it is good substitute of vegetables. To sustain the productivity of such a wonder crop and fulfill the nutritional demand of the ever growing population under changing climate it is necessary to apply integrated agronomic approaches. Integrated management of agronomic practices plays a significant role in the proper growth and development of crops. To test this hypothesis, a field experiment was conducted using Rajmash as a test crop during two consecutive years that is, 2008-2009 and 2009-2010. The experiment was designed using split plot technique. Method of sowing (flat and raised bed) and moisture regime (0.6, 0.8 and 1.0 IW/CPE) was the main plot factor and four nutrient supply systems that is, 100% recommended dose of Nitrogen (NPK) fertilizer – RDF [120:60:40 kg /ha supplied through standard grade Urea (46%N), DAP (46 and 18% P & N) and], 75% RDF +25% through FYM, 75% RDF + 25% by Biocompost and 75% through NPK + 25% N by Azotobacter was taken as sub plot. A total of 24 treatment combinations were replicated three times. Various growth parameters e.g. plant height (cm), number of branches per plant and leaf area index (%), dry matter accumulation (g/plant) at 30, 60, and 90 and at harvest stage as well as grain and straw yield were recorded. Raised bed technique of sowing with moisture regime of 1.0 IW/CPE along with 75% RDNF+25 % N through bio-compost was found most suitable in term of highest total dry matter production. This increase was positively attributed by significant increase in plant height, number of branches per plant and leaf area index of crop. Application of 100% RDNF increased the seed and straw yield significantly in first year while during second year it was maximum, 23.5 q/ha with the application of 75% RDF + 25% N through bio compost and followed by 100% RDF NPK. Minimum seed and straw yields were obtained under 75% RDF + Azotobacter during both the years while highest values were recorded at F_3 and 1.0 IW/CPE ratio. Highest disparity in plant height and leaf area index, under various treatment combinations was recorded at 60 days after sowing of crop.

Key words: Sowing methods, nutrient supply system, moisture regime, food security.

INTRODUCTION

Meeting food demand for the burgeoning population has become a major challenge over entire Asian continent. Agriculture is in the forefront of national and international agenda to assume food security and sound management of natural resource. The challenge to world agriculture is immense. The ever mounting magnitude of the predicted climate change and ever increasing population pressure on future food security have created a major concern for policy makers and scientific community. Agriculture is really suffering due to technological advances because most of the technologies developed are limited only to the laboratory. Prime aim of this research is to find out sustainable agronomic techniques that can improve the production potential without much impairing our natural resources.

Rajmash is famous in the world by its different names viz. in forms of vegetable it is named as French bean, common bean, snap bean and green bean where as in form of pulse it is famous as haricot bean, dry bean, *Rajmash* and navy bean. In Maharashtra region of India it is commonly known as *Shravan* and in Orissa region it is known as *Ghevada* (Singh et al., 1996). Most commonly cultivated *Rajmash* is of two types namely the pole or climber type and the bush or dwarf type. It has very high nutritional value containing 20.69 to 25.81% crude protein, 1.72% fats, 72.42% carbohydrates and 5.83 mg of iron. Moreover, it has good amount of ash content, crude fiber, and total sugars. It is rich in amino acids like tryptophan, methionine, and some phenolic compounds like tannin and polyphenol oxidase (Sood et al., 2003). *Rajmash* is being conventionally cultivated as a mixed crop in the hilly tract of north eastern region of the country. With the improved agronomic practices and application of biotechnical approaches, it could be possible to grow this crop successfully in plains during the winter season. After the development of suitable varieties, the crop has become a major cash crop for the farmers of Gangatic Plain Zone. It has a great potential and will be a good crop to mitigate the nutritional requirement of the increasing population under adverse climatic conditions. From the last two decades, per capita availability of pulses has been progressively declined. Introduction of new pulse crop in non-traditional areas and high yielding varieties as well as intensive techniques, offers possibilities for increasing pulse production. Research workers in India and abroad have found positive response of *Rajmash* to major and minor plant nutrients, sowing time, irrigation and pot culture experiments (Ahlawat, 1996). Though various technological evidences have been carried out after the green revolution but the work is out of reach of the farmer due to inefficient extension services and lack of awareness. No doubt, the crop is one of the most nutritious vegetable but has a total production of only 18 million tones worldwide (provide citation here). Farmers are growing the crop in marginal land with poor management practices and this is one of the reasons for low productivity. Proper management of nutrients and water is one of the prime concerns for the successful cultivation of the crop. Proper seeding technology is also an important factor that decides the plant population which directly affects the total production.

To understand the growth habit under different environmental situations, the plant ideotype is a significant aspect. It is a fact that similar species can behave in different manner under different ideotypic situation. Due to this reason the search for better and more efficient techniques of planting to exploit the full potential of crop has become crucial for agronomists. Selection of proper sowing method plays a very important role to provide favorable condition like placement of seed for their proper germination and subsequent growth. Sowing pattern may depend upon different parameters based on the availability of resources such as soil water, type of soil, time of sowing, environmental condition (Reddy et al., 2010). Irrigation and proper supply of nutrients are important parameters for better growth and development of the crop. It is well know that Pulses are more susceptible to water as compare to other crops. One has to know the amount and stage of irrigation which would be profitable both in term of crop yield and sustainable management of natural resources. In area subjected with water stress, land may not be the limiting factor but in case of water it will be demanding in future. Under those circumstances total return per unit of water is more profitable as compare to return per unit of land (Pereira et al., 2002). Poor management of water resources or irrigation has negative impact on both soil as well as the crop (Kar et al., 2007). Excessive irrigation may cause imbalance in nutrient uptake from field and delays in maturity (Zwart et al., 2004), loss of soil nutrient in the form of leaching and percolation (Jiajie et al., 2013), under stress situation reduces cell division; cell elongation and growth of cell (Kramer, 1972). To maximize return per unit of water application, irrigation should be based on crop demand (Allen et al., 1998). Proper scheduling of irrigation in the context of changing climate helps to improve growth and development of the crop and to maximize yield and minimize input requirement which is more important for the economy of a developing country like India. Integrated nutrient management plays a key role in sustaining soil fertility and crop productivity as well as minimizing the risk of climate change. Improper amount of nutrient supply in crop cause malnourishing or under-nourishing that reduces the production of crop, even all the practices are adopted in appropriate manner (Rajput et al., 2006). Proper amount and method of fertilizer application is far from efficient management in agriculture due to lack of proper awareness that are also main constraint to obtain

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maximum productivity (Patra et al., 2000). Efficient supply system of nutrients aims to use nutrients to target yield depend upon soil and climatic situation. Proper understanding of correlation of various nutrients with each other and combination of minerals and organic fertilizer is necessary to minimize the need of chemical fertilizers. A proper nutrient management will conserve the natural resources by reducing runoff and loss of nutrient from soil. That will help to maintain the sustainable equilibrium within the ecosystem.

The effect of planting methods should be assessed under varying environmental conditions and management practices before the development of appropriate package of technology. Hence, the study has been carried out to find the suitable method of sowing, moisture regime and nutrient supply system for *Rajmash*. Moreover, to study the interaction effect of sowing method, moisture regime and nutrient supply system for different treatments.

MATERIALS AND METHODS

Description of the experimental site

The experiment was conducted at the Agronomy Research farm of the Narendra Deva University of Agriculture and Technology, Narendra Nagar, Kumarganj, Faizabad (U.P.) during Rabi seasons of 2008-2009 and 2009-2010. The experimental site is situated at 26.47°N latitude, 82.120E longitude on altitude of 320 meter. Study site comes under subtropical zone the average rainfall is 1120 mm and temperature varies from 3°C (January) to 41°C (May). It is at a distance of about 42 km from Faizabad district headquarters. The soil of experimental site was clay loam with alkaline pH of 8.1 but the availability of NPK is quite well that is, 105.40, 16.80 and 240.60 kg respectively.

Experimental design and agronomic operations

The split-split-plot experimental design used to test the crop performance with two levels of sowing methods (a). Flat bed [M_1] and (b) Raised bed [M_2] and three moisture regime levels (a) Irrigation at 0.6 IW/CPE [I_1] (b) Irrigation at 0.8 IW/CPE [I_2] (c) Irrigation at 1.0 IW/CPE [I_3] in as main plots and four levels of nutrient supply system (a) 100% Recommended Dose of Fertilizer (RDF) N.P.K [F_1] (b) 75% N.P.K+25% N through F.Y.M [F_2] (c) 75% N.P.K+25% N through Biocompost [F_3] and (d) 75% N.P.K+ 25% N through Azotobactor [F_4] in sub plot. Irrigation was applied only when the IW/CPE ratio value was (i) 0.6 (ii) 0.8 and (iii) 1.0 each treatment combination was replicated thrice and distributed randomly to minimize the error difference between the plots. Each treatment combination was repeated in same way in both years.

After harvest of previous crop, the experimental field was ploughed once with soil turning plough and crossed harrowed. After each operation, leveling was done to obtain the fine tilth. Finally layout was done and plots were marked by small sticks and rope in each block. Total 72 plot with the gross area of 15 m^2 (5x3 m) and net plot size was 10.40 m^2 (4 x 2.60 m) was used to sown the crop. The variety Amber was used as test crop which was the selection of germplasm entry "EC 94457" and was developed at Indian Institute of Pulse Research (IIPR) Kanpur by the concerted efforts of IIPR and All India Co-ordinated Pulse Improvement Project which identified and release in 2006. One hundred seed of Rajmash were tested to know the germination percentage. Germination test was done under laboratory conditions using germination test paper, 92% germination was recorded. After making individual experimental plots, the amount of fertilizer was applied uniformly through urea, single super phosphate, and muriate of potash. One third dose of nitrogen and total phosphorous and potash were applied as basal application. Remaining dose of nitrogen was applied as top dressing in two equal doses each at branching and flowering stage, respectively. Treatment wise urea, single super phosphate and muriate of potash were applied as basal. The seed were sown about 5 to 6 cm deep in rows as per treatment with the help of *kudal* (a hand drawn tillage equipment) at 125 kg/ha and planking was done after sowing. The crop was sown on 23 and 14 November in 2008-2009 and 2009-2010 respectively. One hand weeding was done with the help of Khurpi (state what this is here) before first irrigation. Harvesting was done at physiological maturity when pods turned straw yellow. Harvesting of each plot was done and the net plot size was obtained by leaving 0.50 m at both side in length and 0.60 m at each side in width. The harvested produce was brought to threshing floor after proper tagging. The bundle of harvested produce of each net plot was weighed after complete drying in the sun. The threshing was done manually. The yield and moisture content of grain and straw were recorded. Grain yield was converted at 14% moisture content and straw at oven dry weight basis. Irrigation was scheduled on the basis of IW/CPE ratios.

$$I = \frac{IW}{CPE}$$

Where, I= Irrigation scheduling; IW= Depth of irrigation (cm); CPE= Cumulative pan evaporation.

Volumetric method was applied to measure the irrigation water (m^3/sec.), on the basis of which time required for each plot for irrigation with 6 cm depth was calculated. Time of irrigation given as per treatment which was worked out on the basis of formula given as under:

$$T_a = \frac{AD}{Q}$$

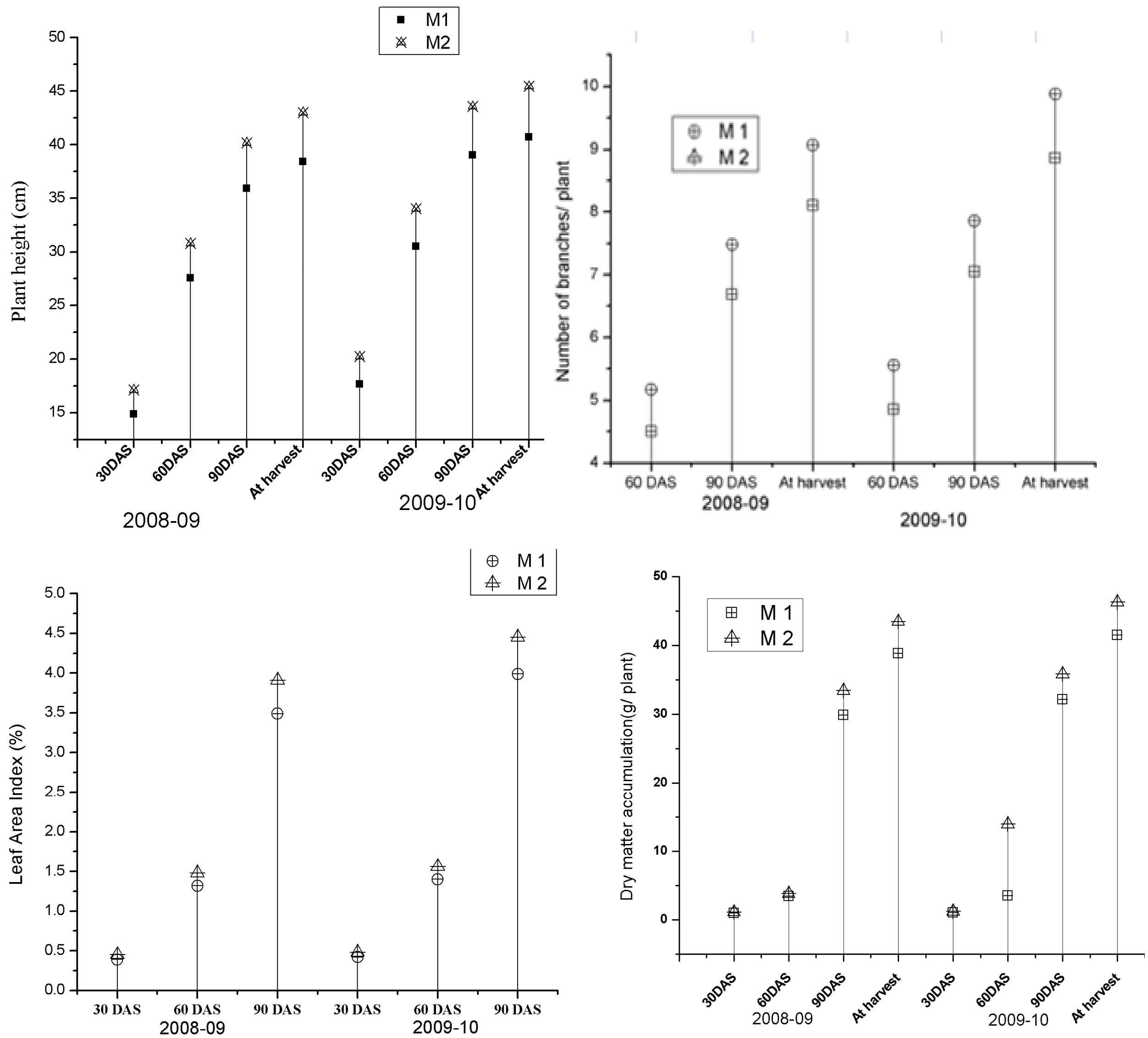
Where, T_a = time of application of water (seconds); A = area of plot to be irrigated ($m^{2)}$; D = depth of water to be provided (mm) Q = discharge liters/sec.

Discharge was measured with the help of parshall flume, which was installed in the irrigation channel as per method described by Parshall (1941). Statistical differences between different planting methods, moisture regime and nutrient supply system levels and their interaction effects on plant height, number of branches/plant, LAI and total dry matter accumulation were tested with Fisher's least significant difference (p=0.05) test (Fisher and Yates, 1949) using analysis of variance (ANOVA) for a split plot design as described by Panse and Sukhatme (1967). All the statistical analyses were done by using SPSS 8.0 and graphs were prepared with Origin plot 8.0.

RESULTS AND DISCUSSION

Plant height

A cursory glance over the data of plant height revealed that the rate of growth was initially slow and attained maximum between 30 to 90 DAS that may be considered as grand growth phase. Thereafter, it increased with



M_1-Flat bed; M_2-Raised bed

Figure 1. Number of primary branches/plant, Leaf Area Index (%), Plant height (cm), Dry matter accumulation (g/plant) at various growth stages of Rajmash crop as affected by planting methods.

relatively slow rate. A significant difference (p=0.05) in plant height was found under raised and flat bed sowing (Figure 1 and Table 1).

Maximum plant height was observed at 30, 60, 90 DAS and at harvest. During both years increase in plant height was observed under raised bed because of full utilization of applied water that enhances water use efficiency and also due to the elimination of the crust form below root zone that improves physical property of soil (Fahong et al., 2004). Different moisture regimes did not affect the plant height at 30 DAS in 2008-2009 season while it influenced the height significantly at 90 DAS and at harvest in both year (Figure 1). Moisture regimes of 1.0 IW/CPE performed significantly better than 0.6 IW/CPE and at par with 0.8 IW/CPE. This is most probably due to increase in root proliferation resulting in increase in uptake of nutrients which translated into higher crop growth (Sarkar, 2005). In case of nutrient supply system, the maximum plant height was observed under F_1 (100% RDF NPK) although the differences in plant height at 30 DAS were not significant in 2008-2009 (Figure 1). In year 2009-2010 highest plant height was recorded under F_3 (75% RDF + 25% N through bio-compost) this was significantly higher with F_2 and F_3 and at par with F_1.addition of bio-compost enhanced nutrient uptake mainly NPK resulting in increase in plant height

Table 1. Analysis of variance for different parameters at 90 DAS.

Parameter	Source of variation							
	Years	M	I	M X I	F	M X F	I X F	M X I X F
Seed yield (q/ha)	2008-2009	**	***	ns	**	ns	*	ns
	2009-2010	**	***	*	**	ns	**	ns
Straw yield (q/ha)	2008-2009	**	***	ns	***	ns	ns	ns
	2009-2010	*	***	ns	**	ns	ns	ns
Plant height (cm) at 90 DAS	2008-2009	**	*	ns	***	ns	ns	ns
	2009-2010	**	*	ns	***	ns	ns	ns
Number of branches per plant at 90 DAS	2008-2009	**	**	ns	***	ns	ns	ns
	2009-2010	ns	ns	ns	ns	ns	ns	ns
LAI at 90 DAS	2008-2009	***	**	ns	***	ns	ns	ns
	2009-2010	***	**	ns	***	ns	ns	ns
Dry matter accumulation (g/plant) at 90 DAS	2008-2009	***	**	ns	**	ns	ns	ns
	2009-2010	***	**	ns	**	ns	ns	ns

Where , M= Methods of Sowing, I= Moisture regieme and F = Fertilizer management

(Adesemoye et al., 2008).

Number of branches per plants

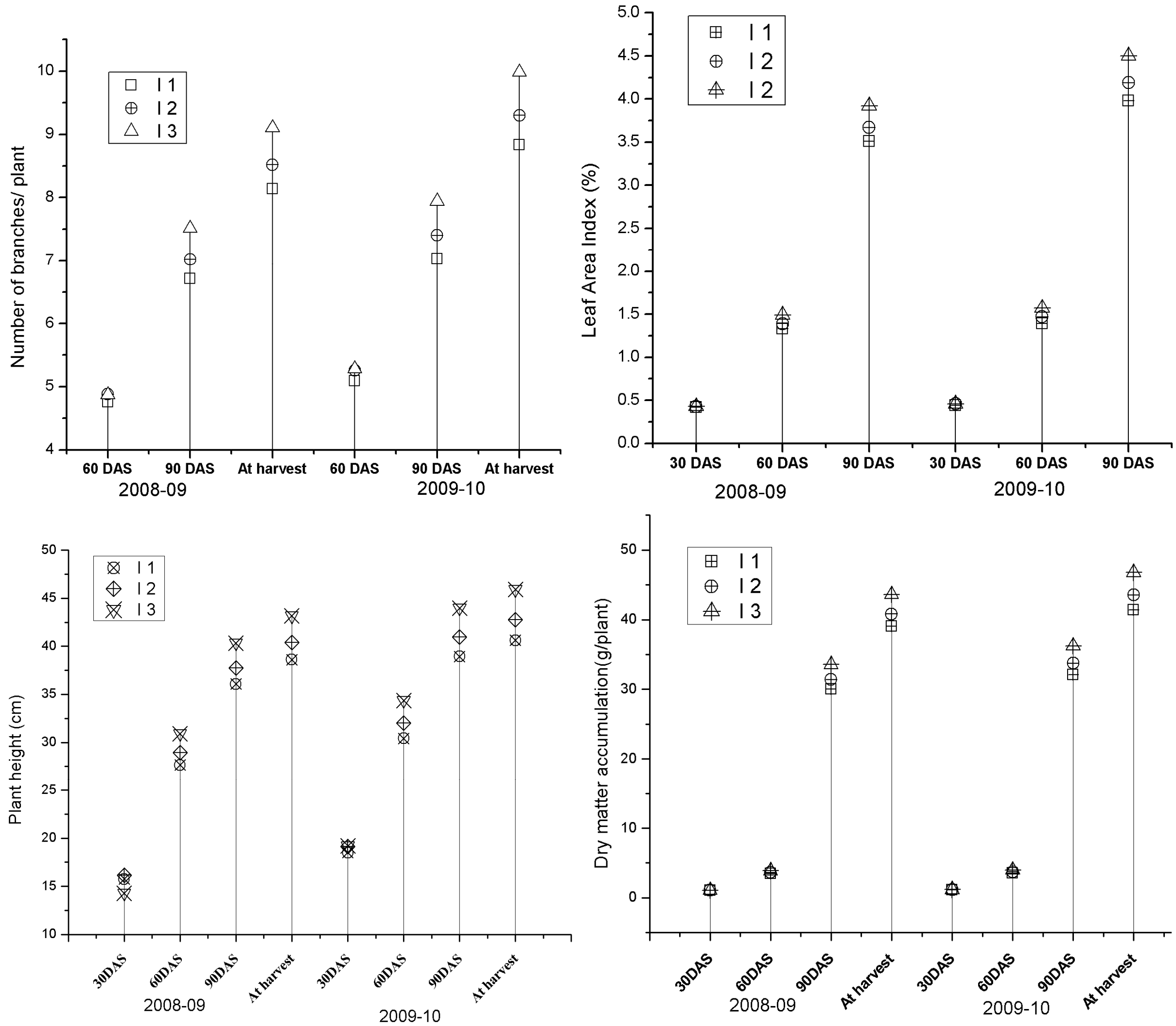
The data with respect to number of branches plant^{-1} as influenced by sowing methods, moisture regimes and nutrient supply systems are presented in Figure 1. The data indicated that the significantly higher number of branches plant^{-1} was recorded under raised bed sowing as compared to flatbed sowing at 60, 90, DAS and at harvest (Table 1). Similar trend was observed during second year of experimentation at 60, 90 DAS and at harvest. This might be due to favorable conditions provided by raised bed technique by improving emergence and reducing soil resistance (providing better tilth to germinate the plant) (Valenciano et al., 2006). The various moisture regimes did not affect the number of branches/ plant at 60 and 90 DAS during first year while at harvest significantly more branches plant^{-1} were observed under 1.0 IW/ CPE as compared to 0.6 and 0.8 IW/CPE (Figure 3).

In case of nutrient supply system, significantly higher number of branches were observed with (100% RDF NPK) as compared to F_2 (75% RDF NPK + 25% N through FYM) and F_4 (75% RDF NPK + Azotobactor) and was at par with F_3 at all the growth stages in year 2008-2009 while in the second year maximum branches were recorded under F_3 (75% RDF NPK + 25% N through biocompost) as compared to F_2 (75% RDF NPK + 25% N through FYM) and F_4 (75% RDF NPK + Azotobactor) and at par with F_1 (100% RDF NPK) at all the growth stages (60, 90 DAS and at harvest) (Figure 3). This might be due to increase in decomposition of nitrogenous fertilizer which enhances the rate of cell division resulting in more branches (Phiri et al., 2000).

Leaf area index (%)

The periodic data on leaf area index (LAI) have been presented in Figure 2. A cursory glance over the data indicated that leaf area index was increased up to 90 DAS stage because up to that period plant is in active growth phase (Sinclair, 1994) after that it enters into senescence phase.

In case of planting pattern higher leaf area index was recorded at 30 DAS in both the year under raised bed sowing as compared to flatbed sowing because of improvement in translocation of nutrient and water in raised bed (Sardana et al., 2000). The various moisture regimes did not influence the leaf area index at 30 DAS during both years. Significantly higher leaf area index was recorded with the moisture regime of 1.0 as compared that 0.6 and 0.8 IW/CPE at 60 and 90 DAS in both years (Figure 2 and Table 1). The various nutrient supply systems did not affect the LAI at 30 DAS during both years of investigation. At 60 and 90 DAS significantly higher LAI was recorded under treatment F3 (100% RDF NPK through chemical fertilizers) and this was significantly higher than that recorded under F_2 and F_4 and at par with F_1 (Figure 3). Raised bed technique



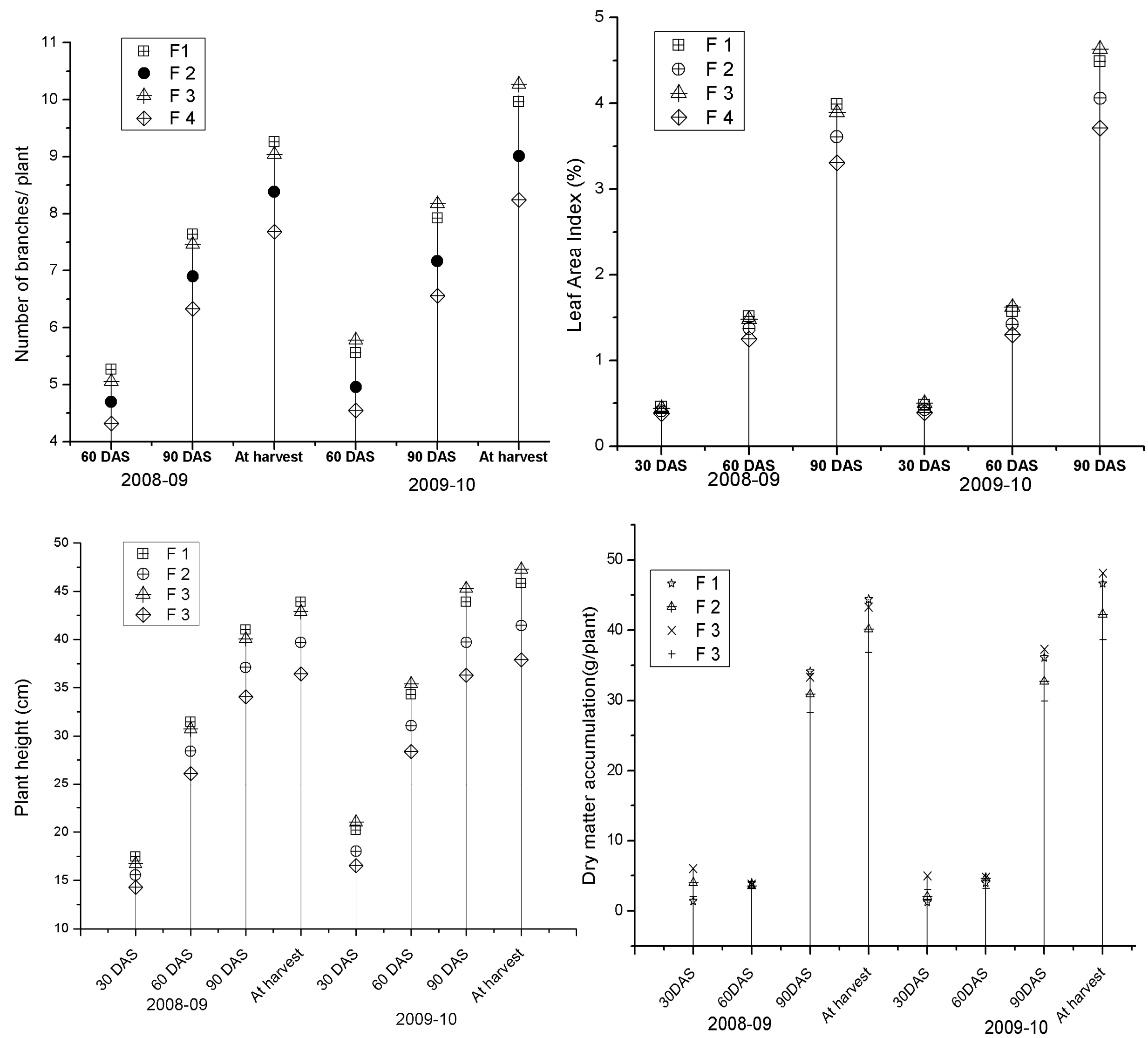
I_1 - 0.6 IW/CPE; I_2 - 0.8 IW/CPE and I_3 -1.0 IW/CPE

Figure 2. Number of primary branches/plant, Leaf Area Index (%), Plant height (cm), Dry matter accumulation (g/plant) at various growth stages of Rajmash crop as affected by Moisture regime IW/CPE.

under efficient supply of water and proper nutrient management improve the root growth of plant which enhances leaf area duration as well as size of leaf this might be reason for highest LAI (Kundu and Sarkar, 2009).

Dry mater accumulation

Analogous to growth character, the dry matter production increased with the age of crop (Kiziloglu et al., 2010) increased rate in dry matter content was noticed between 60 to 90 DAS closely followed by 30 to 60 DAS indicated that the active growth period prolonged between 30 to 90 DAS while highest value was observed at harvest. The higher dry matter accumulation was noticed with raised sowing as compared to flat bed at 60, 90 DAS and at harvest stages of crop growth (Figure 3) in both years while at 30 DAS the value was not significant for the year 2008-2009 due to poor establishment of seedlings. A cursory glance over the data presented in Figure 3 revealed that moisture regime affected the dry matter accumulation from initial stages of growth till harvest. The differences between successive levels of moisture were significant at all the growth stages of crop except at 30 DAS. Maximum dry matter production was noticed under 1.0 IW/CPE (43.62) which was 19 and 10% higher than those obtained under 0.6 and 0.8 IW/CPE ratios in both years (Figure 3). This might be due to improvement in physiological processes



F$_1$-100% RDF, N.P.K; **F**$_2$-75% N.P.K+25% through F.Y.M; **F**$_3$-75% N.P.K+25% through Biocompost and **F**$_4$-75% N.P.K+25% through Azotobactor

Figure 3. Number of primary branches/plant, Leaf Area Index (%), Plant height (cm), Dry matter accumulation (g/plant) at various growth stages of Rajmash crop as affected by Nutrient supply system.

in the plant that are directly responsible for increase in dry matter production in the plant (Lu et al., 2000). Different fertility levels did not influence dry matter accumulation per plant at 30 DAS, significantly probably due to less absorption of nutrient during early stage and low radiation use efficiency (Cirilo and Andrade, 1994) but at 60, 90 DAS and at harvest the maximum dry matter accumulation was recorded under F_1 (100% RDF NPK) as compared to F_2 (75% RDF NPK +25% N through FYM) and F_4 (75% RDF NPK + Azotobactor) and at par with F_3 (75% RDF NPK + 25% N through biocompost). A similar trend in dry matter accumulation was observed for next year (Figure 3).

Seed, straw and biological yield

The data on seed and straw yields obtained as influenced by sowing methods moisture regimes and nutrient supply system have been given in Table 2. An examination of data manifests that sowing methods had significant impact (Table 1) on seed yield of Rajmash. The more seed yield of 30.22 q/ha was obtained under raised bed sowing than that obtained under flat bed sowing (27.36 q/ha) respectively. During next year the same trend was also found. Moisture had significant impact on seed yield of *Rajmash* with increasing moisture supply from 0.6 to 1.0 IW/CPE. The maximum seed yield of (23.05 q/ha)

Table 2. Seed Yield, straw yield and biological yield as influenced by sowing methods, moisture regimes and nutrient supply system.

Treatment	2008-2009			2009-2010		
	Seed Yield (q/ha)	Straw yield (q/ha)	Biological yield (q/ha)	Seed Yield (q/ha)	Straw yield (q/ha)	Biological yield (q/ha)
Sowing methods						
M_1-Flat bed	20.77	27.36	42.31	21.1	28.86	42.31
M_2-Raised bed	21.74	30.22	41.43	22.5	31.08	42.17
SEM±	0.31	0.4	0.2	0.4	0.62	0.13
CD AT 5%	0.97	1.25	0.63	1.26	1.94	0.41
Moisture regime IW/CPE						
I_1 - 0.6 IW/CPE	18.38	22.07	44.76	17.12	22.71	43.05
I_2 - 0.6 IW/CPE	22.33	30.85	40.45	23.86	33.05	41.97
I_3- 0.6 IW/CPE	23.05	33.45	40.41	24.43	34.15	41.69
SEM±	0.38	0.49	0.25	0.49	0.75	0.16
CD AT 5%	1.19	1.53	0.77	1.54	2.37	0.5
Nutrient supply system						
F_1-100% RDF, N.P.K	20.71	31.02	41.7	23.03	31.34	42.39
F_2-75% N.P.K+25% Through F.Y.M	22.25	29	41.97	21.03	29.05	42.01
F_3-75% N.P.K+25% Through Biocompost	19.67	29.84	40	23.5	33.67	40.9
F_4-75% N.P.K+25% Through Azotobacter	0.34	25.31	43.82	19.66	25.85	43.66
SEM±	0.97	0.5	0.61	0.44	0.74	0.58
CD AT 5%		1.44	1.75	1.26	2.11	1.67

was credited under wettest moisture regimes of 1.0 IW/CPE followed by 0.8 IW/CPE (22.33 q/ha) and minimum seed yield (18.38 q/ha) was recorded at 0.6 IW/CPE (Driest regimes). Wettest moisture regime (1.0 IW/CPE) registered significant increase than 0.6 IW/CPE and at par with 0.8 IW/CPE and this is 45.25 and 14.34% higher than those of 0.6 and 0.8 IW/CPE, respectively. In next year same trend was found. Different nutrient supply systems influenced the seed yield of *Rajmash* significantly. It increased significantly due to nutrients supply system under F_1 (100% RDF NPK) (22.38 q/ha) as compared to F_2 (75% RDF NPK + 25% N through FYM) and F_4 (75% RDF NPK + azotobacter) and at par with treatment F_3 (75% RDF NPK +25% N through bio-compost) respectively. While in next year the maximum seed yield was recorded under F_3 (75% RDF NPK + 25% N through biocompost) (23.50 q/ha) which was significantly higher than that recorded under F_2 and F_1 and at par with F_1 (100% RDF NPK) respectively.

Conclusion

Set of data presented in the study revealed that in case of sowing methods significant increase in plant height, number of branches plant^{-1} leaf area index as well as dry matter accumulation were observed with raised bed sowing method due to improvement in root proliferation and proper uptake of nutrient and water from soil. While in case of various moisture regimes significant increase in plant height, number of primary and secondary branches per plant, leaf area index as well as dry matter accumulation was observed with increasing levels of moisture. The wettest moisture regime (0.1 IW/CPE) exhibited its superiority with recording highest values of almost all the growth parameters. In case of different nutrient supply systems application of 100% RDF, NPK increased the plant height, number of primary and secondary branches per plant, leaf area index, total dry matter production, significantly at all the growth stages. While during second year all the above parameters recorded highest values at application rates of 75% RDF NPK + 25% N through bio-compost. Adequate moisture supply favorably increased the response of different nutrient supply systems in terms of growth and biomass production. The highest values of all the growth and yield parameters were recorded at F_3 and 1.0 IW/CPE ratio while the minimum values were noticed under the driest moisture regime (0.6 IW/CPE) with F_4. Finally it has been concluded that the maximum value of all the parameter was observed under raised bed planting method with moisture regime of 1.0 IW/CPE along and nutrient supply system of 75% RDF (120, 60, 40 NPK) + 25% N through bio compost. Thus it is to be considered as best combination of agronomic practices for the successful cultivation of *Rajmash* in plains of Uttar Pradesh, India.

Conflict of Interest

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

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