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Effect of Integrated Nutrient Management on Yield of Castor (*Ricinus comunis* L.) in Typic Ustochrept Soil of Hisar, Haryana

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ABSTRACT: The present study was conducted for five rainy seasons (*kharif*) of 2005 to 2009 at a fixed site at the farm of AICRP for Dryland Agriculture, CCS Haryana Agricultural University, Hisar, India to study the effect of organic, inorganic and biofertilizer on seed yield of castor in Aridisols. The experiment consisted of nine treatments, each replicated thrice in a randomized block design. The treatments tried had significant effect on seed yield of castor over control except the treatment of application of 20 kg N/ha during all the five seasons. Conjunctive use of organic and biofertilizer with inorganic fertilizer application (20 kg N/ha) gave promising results when compared with 40 kg N/ha alone. This indicates the additive response to biofertilizers and organics (4 t FYM/ha). Increase in application of N from N_{40} to N_{60} did not affect the seed yield of castor significantly when compared with 40 kg N/ha at the same level of phosphorus application. The microbial count of *Azotobacter* and PSB was the highest at 30 and 60 days after sowing (DAS), respectively irrespective of treatments. Application of N_{60} P_{20} had recorded the highest benefit-cost ratio (BCR) of 1.58 closely followed by N_{40} P_{20} (1.54).

Key words: *Azotobacter,* FYM, yield, phosphate solubilizing bacteria, viable counts

In India, of late castor (*Ricinus comunis* L.) farming has attained commercial significance with the pioneering development and cultivation of high yielding, pest resistant varieties/hybrids both under rainfed and irrigated situations. India is the world's largest producer of the castor contributes to around 65% of the world's total production and dominating the global trade with a share of more than 8%. India produces around 8 lakh tons of castor seed and around 3 lakh tons of castor oil. India meets more than 80% of the demand of castor oil, thereby enjoying a dominant position in the World Castor Scenario. Although castor is grown in almost all the states in India; Gujarat, Andhra Pradesh, Rajasthan and Maharashtra account for about 40, 40, 9 and 4% of the total area under the crop, respectively. Gujarat accounts for nearly 68% of the country's castor production. Castor productivity is the highest in Gujarat (1864 kg/ha) followed by Rajasthan (1412 kg/ha), Karnataka (824 kg/ha) and Andhra Pradesh (454 kg/ha). Despite phenomenal increase witnessed in the production and productivity over the last decade, there are wide regional disparities in the productivity of castor. With the exception of Gujarat and Rajasthan States, where the productivity has registered a fourfold increase since 1970, the general productivity level of castor in other states of the country is very low. A multitude of factors such as its cultivation in sub marginal and marginal lands, uncertainty and erratic distribution of rainfall, delayed sowings, poor management of the crop with little or no inputs and use of poor quality seed are responsible for low yields under rainfed situations. For these reasons, castor crop deserves focused attention on extension of its area and increase of yield.

Castor can be grown in dry arid climate and grows best on light sandy loam soils. The yields can be considerably increased if adequate fertilizers are used besides other agronomic management practices. But, the chemical fertilizers are quite expensive, and the small and marginal farmers are unable to use these fertilizers in required quantities due to their poor economic conditions besides risk of crop failure. Therefore, it is urgent need to substitute a part of chemical fertilizer through organic manures/wastes and biofertilizers. Farm yard manure and bacterial cultures are easily available and cheap source of nutrients. In the light of these observations, an experiment is laid out to see the effect of conjunctive use of organic, inorganic and biofertilizer on cultivation of castor under dryland conditions for a period of five years from 2005 to 2009.

Materials and Methods

Study area

The study was conducted at CCS Haryana Agricultural University, Hisar Centre of All India Coordinated Research Project for Dryland Agriculture (AICRPDA), in the Haryana region of India which is geographically located between 29° 9' 11'' N latitude, 75° 43' 6'' E longitude, and at an altitude of 212 m above mean sea level, where the summer is dry and hot while the winter is cool. The average annual rainfall is about 360 mm, roughly much needed (75-80%) is received during the south-west monsoon season (June to September). Dry spells of more than 3 weeks may occur even during this season. In the post-monsoon winter season (October to April), few light showers i.e. 10 to 15% of the annual rainfall are received from westerly depressions. Generally mono-cropping is practiced due to scanty and erratic rainfall.

Soil characteristics

Initial soil samples (up to 120 cm) were taken by a hand auger, air-dried, sieved to 2-mm particle diameter, and analyzed for physical and chemical characteristics. Chemical and physical analysis results of soil samples taken in 15 cm increments up to 30 cm depth and thereafter in 30 cm up to 120 cm soil depth are presented in Table 1.

The soil of the experimental area classified as coarse loamy Typic Ustochrept according to Soil Survey Staff (1992), is alkaline but non saline and has loamy sand to sandy loam texture, low lime content and inadequate organic C and phosphorus. Nitrogen was also at a low level while potassium was high in upper as well as in the deeper layers. Determinations of pH, $CaCO_{3,}$ organic carbon, available N, P & K (Jackson, 2005), EC (Richards, 1954), and particle size (Piper, 1966) were made on soil samples taken from five soil levels (0-15, 15-30, 30-60, 60-90 and 90-120 cm). For bacterial population in rhizosphere, soil samples were collected at 30 days after sowing (DAS) & at harvest and were serially diluted and plated on Jensen, Malate and Pilovaskaya medium for *Azotobacter* and PSB counts.

Treatments and experimental design

The experiment was started during the *kharif* season of 2005 at a fixed site. The experiment was laid out in randomized block design, replicated 3 times with 9 treatments: T_1 - Control (N_0P_0 and no inoculation); T_2 - N_{20} kg/ha; T_3 - N_{40} kg/ha ; T_4 – $N_{20}P_{20}$ kg/ha; T_5 - $N_{40}P_{20}$ kg/ha; T_6 - $N_{60}P_{20}$ kg/ha; T_7 - $N_{20}P_{10}$ kg/ha + FYM @ 4 t/ha ; T_8 - FYM @ 4 t/ha + seed inoculation with mixed bio-fertilizer (*Azotobacter chroococcum* and phosphate solubilizing bacterium-PSB); T_9 - T_2 + T_8 . The mixed bio-fertilizer used as inoculants were obtained from culture collection, Department of Microbiology, CCS Haryana Agricultural University, Hisar which were prepared by mixing *Azotobacter chroococcum* strain MAC 68 and phosphate solubilizing bacterium *Bacillus polymyxa* strain BP or mixture of two in equal proportion. Seeds of castor were inoculated with packet of charcoal based inoculants. Each treatment was applied to castor crop every year. In addition to the treatments, standard agronomic practices of the region were used for the castor.

Generally, this crop is not fertilized by the farmers of this region due to their poor conditions and risk factors. However, the normal recommended dose of fertilizer for light and low fertile soils are 40 kg N (through urea) out of which half dose of N is applied as basal and remaining half after two months of sowing. No phosphorus and potassium fertilizer is recommended. In our trial, entire quantity of N (through urea) was hand broadcasted at planting and P (through single super phosphate) was drilled basally. The plot size was 5.0 m x 4.5 m. Seeds of castor (cultivar DCH 7) were sown @ 7.5 kg/ha by dibbling method at spacing of 90 cm x 30 cm during the mid of July except in the years of 2008 and 2009 where the seeding was done in the last week of July and were always harvested in last week of December.

Statistical analysis

In order to evaluate the comparative performance of the various treatments, data were analyzed by using the technique of analysis of variance described by Fisher (1958). All tests of significance were made at 5% level.

Results and Discussion

Weather and climate

The local climatologically data (except rainfall) during different *kharif* seasons were collected at the meteorological station situated one kilometer away from the experimental site and are presented in Table 2.

The data on rainfall was recorded by the rainguage located at the experimental site and reveal that out of five seasons, three seasons (2006, 2007 and 2009) received low rainfall as against the normal rainfall of 329.2 mm spread over 29 rainy days. Normal and below normal years were classified depending upon the total rainfall, rainfall received during the months of crop growth and by the crop yields. Accordingly, the seasons 2005, 2007 and 2008 were qualified for above normal category whereas 2006 and 2009 were below normal. An average rainfall of 286.1 mm was received for 5 years period 2005-2009 at AICRPDA Research Farm, Hisar during July to December in 15 rainy days. July was found as the wettest month with average monthly rainfall of 100.3 mm in 6 rainy days followed by the month of August and September with an average monthly rainfall of 90.3 mm in 4 rainy days. More or less variations among the rest of the climatic data compared to long term average were also observed.

Amongst the seasons, the maximum and minimum temperature ranged from 19.1 to 44.1 and 1.6 to 28.9^{o}C, respectively. The relative humidity varied from 18 to 81% in the evening to 46 to 98% in the morning. The average wind speed ranged from 0.9 to 10.6 km/hr. The bright sunshine hours ranged between 0.1 on a cloudy day to 10.3 on a clear day. Evaporation from open pan evaporimeter ranged between 1.1 to 12.4 mm/day. The details of dry spells of more than two weeks that occurred during crop growth period in different years are presented in Table 3.

The crop experienced three dry spells of more than two weeks totaling 125 days in 2005; two in 2006 totaling 146 days; three in 2007 totaling 106 days; four in 2008 totaling 118 days and two in 2009 totaling 138 days. The long dry spells in the season 2006 and 2009 affected the performance of crop adversely due to inadequate soil moisture during October and November. The data on rainfall received during the crop growth stages in various years are presented in Table 4.

Yield

The seed yield of castor as influenced by different treatments during five seasons (2005 to 2009) is presented in Table 5. It is clear that the yield of castor varied widely from year to year and it varied from 962 to 1407, 244 to 437, 755 to 1319, 503 to 1066 and 259 to 784 kg/ha for the different treatments evaluated during 2005, 2006, 2007, 2008 and 2009, respectively. During 2005, the yield levels recorded were highest over 2007 and 2008 due to favorable weather conditions during grand growth period with timely and evenly distribution of rainfall. The season 2008 though received well distributed rainfall and more or less at par seasonal rainfall compared to 2005 but heavy rainfall event of 170 mm at the time of germination and seedling stage led to decrease in yield. The yield levels recorded the were lowest in the seasons 2006 and 2009 due to heavy and erratic distribution of rainfall between crop growth periods of 1-30 in 2006 and 30-60 days from sowing in 2009 besides a long dry spell during later stages of crop growth. The season 2006 and 2009 received 88 and 12% less rainfall as against the crop seasonal rainfall of 329.2 mm. There was significant effect of various treatments on seed yield over control except the treatment of 20 kg N/ha irrespective of years.

The pooled data on seed yield of castor differed significantly due to different treatments. Application of 60 kg N + 20 kg P_2O_5/ha treatment recorded significantly higher seed yield (1003 kg/ha) over control (509 kg/ha). Significantly higher seed yield (683-1003 kg/ha) due to various treatments was also observed over application of 20 kg N/ha (576 kg/ha). Seed yield of castor also increased significantly by 8.9% (1003 kg/ha) compared to recommended dose of fertilizer i.e. 40 kg N/ha (921 kg/ha). Significant increase in seed yield to the level of 33.1 to 38.3% was noticed at 40 kg and 60 kg N treatments with same level of phosphorus application i.e. 20 kg P_2O_5/ha when compared with 20 kg N + 20 kg P_2O_5/ha treatment (725 kg/ha) whereas increase in application of N from N_{40} to N_{60} did not affect the seed yield of castor (1003 kg/ha) significantly when compared with 40 kg N/ha at the same level of phosphorus application (965 kg/ha).

Application of 4 t FYM along with inoculation with mixed biofertilizer and conjunctive use of inorganic, organic and biofertilizer (N_{20} + 4 t FYM + MB) resulted in significant increase in seed yield to the tune of 18.6 and 46.7%, respectively over treatment of 20 kg N/ha alone (576 kg/ha). This indicates the additive response to mixed biofertilizer (PSB + *Azotobacter*) and organics (4 t FYM) however; the response was less in the absence of chemical fertilizer.

Critical evaluation of the seed yield with different treatments clearly indicated that integrated use of organic (4 t FYM) and mixed biofertilizer (PSB + Azotobacter) resulted in 50% increase in seed yield at the same level of fertilizer application (20 kg N/ha alone) and gave almost at par yield when compared with application of 40 kg N/ha alone. This in turn indicated that dependence on inorganic fertilizer can be minimized by the use of organic and biofertilizers. The above findings are in conformity with the studies of Wani *et al.* (1985), Narula et al. (1991), Suneja and Lakshminarayana (1998), Lakshminarayana (2000 a and b), Raj and Sangwan (2003).

The effect of selected treatments on biomass partitioning of castor (pooled mean) at physiological maturity (Table 6) indicated that total biomass was higher by 60.4% in N_{40} P_{20} treatment as compared to other treatments (49%) over control.

Soil biological properties

The biological properties in terms of population of N fixer (*Azotobacter*) and P solubilizer (PSB) are presented in Table 7. The results revealed that the microbial count of *Azotobacter* and PSB was the highest at 30 (18.8 x10^4 cfu/g soil) and 60 (84.7 x 10^5 cfu/g soil) days after sowing, respectively irrespective of treatments. The count reduced at harvesting stage of the crop due to moisture stress. Among the treatments, integrated use of inorganic, organic and biofertilizer (T_9) supported higher population of N fixer and P solubilizer followed by use of 4 t FYM + mixed biofertilizer (T_8). Before sowing, pooled mean for the total N fixer and P solubilizer count was 6.4 x 10^4 and 18.7 x 10^5 cfu/g soils, respectively.

Economics

The benefit-cost ratios (BCR) 1.36 and 1.49 were obtained with N_{20} + 4 t FYM + MB and N_{40} treatments, respectively (Table 5) while application of N_{60} P_{20} had recorded the highest BCR 1.58 closely followed by N_{40} P_{20} (1.54). The percent increase in net return over control ranged from 15.8 to 92.7 being maximum from N_{60} P_{20} and minimum with N_{20} treatment.

Table 1 : Some soil fertility values related to the experimental area

Depths (cm)	Texture				pH (1:2)	EC (dS/m)	O.C (%)	$CaCO_3$ (%)	Available nutrients (kg/ha)		
	Sand (%)	Silt (%)	Clay (%)	Texture class					N	P	K
0.-15	57	24	19	SL	8.1	0.14	0.16	Tr	150.0	6.9	332.7
15-30	66	21	13	SL	8.2	0.09	0.16	Tr	148.2	10.0	330.2
30-60	70	19	11	SL	8.2	0.11	0.13	Tr	152.8	5.2	370.4
60-90	84	13	03	LS	8.1	0.13	0.13	Tr	140.8	9.4	360.1
90-120	80	15	05	LS	8.0	0.11	0.12	Tr	137.5	10.2	360.8

SL = Sandy loam, LS = Loamy sand, Tr: = Traces

Table 2 : Climatic data during crop season (July to December) of the region during the study period 2005-2009

Parameters	Years					
	2005	2006	2007	2008	2009	LTA
Rainfall (mm)	371.8 (17)	174.8 (11)	227.1 (14)	362.0 (21)	294.6 (12)	329.2 (29)
Max.Temp. (^oC)	19.7-44.1	20.5-39.2	19.1-41.0	21.4-38.3	21.6-43.2	20.2-40.9
Mini. Temp. (^oC)	1.6-28.6	4.2-28.9	2.6-28.0	2.9-27.4	2.0-28.2	4.3-25.7
Bright sun shine hours	2.7-10.3	0.1-10.3	2.1-10.2	3.5-10.1	2.1-10.1	5.9-9.0
Wind speed (km/hr)	0.9-10.6	1.8-9.1	1.3-10.1	1.5-9.4	1.9-9.7	2.6-11.4
Evaporation (mm/day)	1.1-12.4	1.4-11.0	1.2-12.4	1.1-7.2	1.4-11.9	1.9-12.2
Relative humidity (%)						
Morning	50-95	62-98	48-94	69-96	46-95	51-84
Evening	23-81	32-74	22-65	25-81	18-69	26-58

Figures in parentheses represent total number of rainy days LTA = Long term average, 1970-2004

Table 3 : Dry spells of more than two weeks that occurred during crop growth period

Year	Period	No. of days
2005	Aug 08 - Sep 08; Sep 25 - Nov 03; Nov 05 - Dec 27	125
2006	Aug 01 - 31; Sep 03 - Dec 26	146
2007	Aug 08 - 24; Aug 26 - Sep 05; Sep 15 - Dec 01	106
2008	Aug 17 - Sep 18; Sep 21 - Oct 07; Oct 09 - Nov 19; Nov 21 - Dec 16	118
2009	July 29 - Aug 30; Sep 13 - Dec 26	138

Table 4 : Distribution of rainfall (mm) and number of effective rainy days during crop growth period

Years	Days from sowing					Total rainfall	Effective rainy days (> 15 mm)	MET classification based on normal rainfall
	1-30	30-60	60-90	90-120	120-till harvest			
2005	38.2 (3)	165.0 (5)	27.3 (4)	9.4 (1)	-	239.9 (13)	4	Above normal
2006	116.9 (8)	53.4 (2)	-	-	4.5 (1)	174.8 (11)	4	Below normal
2007	89.1 (3)	105.2 (5)	-	-	4.4 (2)	198.7 (10)	5	Above normal
2008	170.0 (9)	70.9 (2)	4.2 (1)	2.1 (1)	1.1 (1)	248.3 (14)	7	Above normal
2009	24.4 (1)	216 (6)	-	-	-	240.4 (7)	4	Below normal

MET = Meteorology, Figures in parentheses indicate total number of rainy days

Table 5 : Seed yield of castor (kg/ha) as influenced by various treatments

Treatments	Years						
	2005	2006	2007	2008	2009	Pooled mean	BCR
T_1- Control (N_0P_0)	822	204	755	503	259	509	0.82
T_2- N_{20}	892	259	814	592	325	576	0.95
T_3- N_{40}	1304	414	1243	962	681	921	1.49
T_4- $N_{20}P_{20}$	1007	385	1020	725	488	725	1.12
T_5- $N_{40}P_{20}$	1318	429	1300	1021	755	965	1.54
T_6- $N_{60}P_{20}$	1407	437	1319	1066	784	1003	1.58
T_7- $N_{20}P_{10}$ + 4 t FYM	1037	385	1168	858	592	808	1.28
T_8- 4 t FYM + MB	992	325	962	651	485	683	1.01
T_9- N_{20} + 4 t FYM + MB	1096	407	1184	902	636	845	1.36
SEm ±	44	26	67	42	57	25	-
CD (P=0.05)	133	77	200	127	172	76	-

MB= Mixed biofertilizer (*Azotobacter chroococcum* and phosphate solubilizing bacterium-PSB), BCR = Benefit-cost ratio

Table 6 : Biomass partitioning (g/m^2) of castor at physiological maturity (selected treatments - pooled of 5 years)

Treatments	Biomass (unit)				
	Leaf	Stem	Root	Capsules in raceme	Total
T_1- Control	14.7	46.1	11.1	44.6	116.5
T_2- N_{40}	18.0	60.1	12.6	82.7	173.4
T_3- N_{40} P_{20}	18.6	67.7	14.1	86.5	186.9
T_4- N_{20} + 4 t FYM + MB	17.8	64.3	13.2	78.0	173.3

Table 7 : Count of native population of *Azotobacter* and PSB*

Treatments	*Azotobacter* (x 10^4 cfu/g soil)			PSB (x 10^5 cfu/g soil)		
	30 DAS	60 DAS	At harvest	30 DAS	60 DAS	At harvest
T_1- Control (N_0P_0)	10.5	9.33	6.8	26.7	76.7	20.4
T_2- N_{20}	10.8	5.86	5.4	29.5	71.0	19.3
T_3- N_{40}	11.5	6.05	5.6	28.4	72.0	19.8
T_4- $N_{20}P_{20}$	10.3	6.06	5.6	27.0	87.4	21.0
T_5- $N_{40}P_{20}$	14.4	7.96	6.1	26.8	85.2	20.6
T_6- $N_{60}P_{20}$	15.8	7.60	5.8	28.4	85.8	20.7
T_7- $N_{20}P_{10}$ + 4 t FYM	16.0	11.2	8.9	27.5	75.0	20.1
T_8- 4 t FYM + MB	30.7	15.8	9.7	31.5	102.4	26.5
T_9- N_{20} + 4 t FYM + MB	31.2	18.8	9.9	35.6	106.9	27.1
Mean	18.8	9.8	7.1	29.0	84.7	21.7

*CBS = *Azotobacter* - 6.4 x 10^4, PSB = 18.7 x 10^5, DAS = Days after sowing

Conclusions

Results of present study imply that 50% of recommended dose of chemical fertilizer and 4 tons FYM per hectare in combination with mixed biofertilizer (*Azotobacter chroococcum* and phosphate solubilizing bacterium-PSB) gave promising results in terms of seed yield of castor and benefit-cost ratio when compared to recommended dose of chemical fertilizer (40 kg N/ha). Hence, by following integrated nutrient management approach, dependence on inorganic fertilizer can be reduced as chemical fertilizer may be replaced to some extent by organic manure and biofertilizer which is economically viable for the farmers of dryland region.

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