**Effects of spacing and nitrogen on castor (GAC 11) grown in heavy black soil**

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**ABSTRACT**

 For effect of spacing and nitrogen on castor (GAC 11) grown in heavy black soil of middle Gujarat experiment was carried out at Narmada Irrigation Research Project, Anand Agricultural University, Khandha,Vadodara (Gujarat) during the years 2019-20, 2020-21 and 2021-22. The experiment was laid out in split plot design with three replications. Significantly the highest plant population was recorded under treatment S1 : 60-120-60 cm (Paired row). Growth and yield attributes of castor were remain unaffected due to the different spacing treatments, while, significantly the highest seed yield of castor was recorded under treatment S1 : 60-120-60 cm. Under nitrogen levels treatments, significantly the highest growth and yield attributes of castor like, plant height, number of branches per plant, number of spike per plant, main spike length and number of capsules per main spike and seed yield of castor were recorded under treatments N3: 100 kg/ha which was statistically at par with treatment N2: 75 kg/ha. Significantly the highest seed yield of castor was recorded under treatment S2N3 which was statistically at par with treatments S1N1, S1N2, S1N3, S2N2 & S3N3 ,while interactions effects were found non-significant with respect to growth and yield attributes. Maximum net realization and BCR were recorded under treatments S1N2, S1N3, S2N2 & S2N3, while, low cost of cultivation was found under treatment S1N1.

**Key words**: castor, plant population, paired row spacing, nitrogen, seed yield

**1. INTRODUCTION**

 Castor (*Ricinus communis* L.) is one of the most important non-edible oilseed crops of India. Because of its hardiness, castor plays an important role in the economy of arid and semi-arid regions of the country. Castor oil has great industrial utility as it is used for the manufacture of soaps, refined and perfumed hair oil, printing inks, varnishes, synthetic resins, carbon paper, lubricants, printers, ink, electrical insulation, ointments, cosmetics and processed leather. Castor cake is also a good source of nitrogen (4.3%) and is widely used as manure. In Gujarat castor is cultivated in an area of 7.25 lakh hactares and production of 15.95 lakh tones with productivity of 2201 kg/ha (Anon.2023).

 Optimizing plant spacing and plant population is a simple agronomic technique which may plays an important role in obtaining higher yield. Under black soil conditions, vegetative growth of crop is higher on account of more conservation of soil moisture. Under these circumstances, farmers of middle Gujarat growing castor under heavy black soil are generally preferred wider spacing and therefore, it is very necessary to standardise optimum plant population by adjusting the spacing.

 Fertilizers play a significant role in the modern crop production. They are key inputs contributing about 30 to 70 per cent increase in crop yield. Nitrogen is an essential nutrient needed by all plant to thrive. Efficient utilization of N fertilizers can increase the yield of castor. Enhanced production is possible mainly through appropriate agro techniques such as crop sown at optimum spacing, maintaining optimum plant population and efficient use of nutrients. The present study was, therefore, designed to obtain reasonably higher level of productivity of castor by selecting the suitable plant spacing and nitrogen level under black soil condition of the middle Gujarat region.

**2. MATERIALS AND METHODS**

 Research experiment was carried out to find out the optimum spacing and nitrogen level for castor (GAC 11) during semi *rabi* season (sowing in October month) for the consecutive three years 2019-20, 2020-21 and 2021-22 at Narmada Irrigation Research Project, Anand Agricultural University, Khandha (Gujarat) which represent Middle Gujarat Agroclimatic Zone III and Agro ecological situation IX of Gujarat. The soil of Khandha farm is montmorillonitic and vertisols which is characterized by very deep black clayey, imperfectly drained with low infiltration rate. The initial soil status showed that soil was high in organic carbon (0.88%), medium in available phosphorus (55.04 kg/ha), high in available potassium (981 kg/ha) and alkaline in reaction having pH of 8.44. The experiments were laid out in split plot design with three replications. There were twelve treatment combinations consist of four plant spacing *i.e.,* S1 : 60-120-60 cm (Paired row-18,519 plants/ha), S2 : 60-150-60 cm (Paired row-15,873 plants/ha), S3 : 60-180-60 cm (Paired row-13,888 plants/ha) and S4 : 180 x 60 cm (Farmer’s practice- 9,259 plants/ha) as a main plot and three nitrogen levels *i.e.,* N1 : 50 kg/ha, N2 : 75 kg/ha and N3 : 100 kg/ha as a sub plot. FYM @ 5 t/ha was applied during land preparation. Improved selection variety Gujarat Anand Castor 11 (GAC 11) was used in the experiment, which is recommended for castor growing areas of middle Gujarat under irrigated and rainfed conditions. Castor seeds were dibbled as per the spacing treatments in paired row and without paired row. Gap filling operations were undertaken at 15 days after sowing to maintain uniform plant population. Common dose of Phosphorus @ 50 kg/ha was applied as a basal to all plots. Nitrogen was applied as per the treatments in three splits *i.e.,* 25 % N as a basal, 50 % N at 30 DAS and 25 % N at 60 DAS. Urea and Single super phosphate were used as source for supplying N and P2O5 nutrients respectively. Besides spacing and nutrient management practices, the crop was raised with recommended package of practices. The treatment effects were evaluated in terms of growth, yield attributing parameters, yield and economics. Observations on plant population, plant height, number of branches per plant, number of spike per plant, main spike length and number of capsules per main spike, seed index and seed yield were recorded as per the procedure. Soil analysis at initial and after harvest of crop was done to assess the nutrient content in the soil. Data was analyzed statistically using Fisher’s analysis of variance technique and treatment means were compared using least significant difference test at 5 percent level of probability. The average maximum and minimum temperature during the experimental periods were 33.4 0C and 16.8 0C respectively with average precipitation 1078 mm.

**3. RESULTS AND DISCUSSION**

 The pooled results of three years experimental findings on effect of row spacing and nitrogen on growth, yield attributes, yield and economics of castor have been discussed under different heads.

**3.1 Effect of plant spacing:**

 Plant populations/net plot was significantly increased under paired row spacing treatment S1 : 60-120-60 cm (46.5) over other spacing treatments i.e., S2 : 60-150-60 cm (31.2), S3 : 60-180-60 cm (31.0 ) and S4 : 180 x 60 cm (23.2). This was attributed to more plants were sown per unit area under closer spacing of paired row as compared to normal spacing of farmer’s practices. Porwal *et al.* (2006) and Patel *et al*. (2010) reported the similar results. The pooled results of three years experiment findings showed that growth and yield attributes like, plant height, number of branches per plant, number of spike per plant, main spike length, number of capsules per main spike and seed index of castor (GAC 11) were remain unaffected due to the different spacing treatments. This exhibited that inter row competition was not so severe due to the different paired row spacing and normal spacing. Similar results was reported by Dhimmar (2009).

 Seed yield of castor was significantly influenced due to the spacing treatments. Significantly the highest seed yield (1069 kg/ha) was recorded under treatment S1 : 60-120-60 cm (Paired row) over normal sowing treatment S4: 180 x 60 cm (farmer’s practice) and it was statistically at par with treatment S2 : 60-150-60 cm (Paired row) in pooled results. This can be attributed to more number of plants per unit area under closer spacing of paired row which resulted in higher yield. It appears that paired row planting of castor at 60-120-60 cm could intercept more solar radiation and utilized it more efficiently and thereby increased in yield. These findings corroborates the results of Porwal *et al.* (2006), Patel *et al.* (2009), Patel *et.al*. (2010), Dodiya *et al.* (2016),Shinde *et al.* (2018) and Kowser *et al*. (2021).

**3.2 Effect of nitrogen levels:**

 Growth and yield attributes except seed index were found significant due to the different nitrogen levels treatments. Significantly the highest growth and yield attributes like, plant height (91.0 cm), number of branches per plant (4.27), number of spike per plant (5.51), main spike length (55.1 cm) and number of capsules per main spike (63.8) were recorded under treatments N3: 100 kg/ha which was statistically at par with treatment N2: 75 kg/ha. This improvement in crop growth might be because of the increased availability and uptake of nitrogen at higher N levels. The increasing trend in growth and yield attributes might be due to the reason that nitrogen hastens the metabolic activities in the plant body by synthesizing the tryptophan, a precursor, for the auxins, which in turn increased number of branches per plant. But under limited availability of nitrogen reduce cell division and elongation which ultimately reduced number of branches per plant. More number of branches per plant coupled with better nutrition would have resulted in production of more number of spikes/ plant and capsules/ spike. These results are in agreement with Mathukia and Modhwadia (1993),Venugopal *et al.* (2007), Patel *et al.* (2009),Patel *et al.* (2010) and Man *et al.* (2017).

 Significantly the highest seed yield of castor (1069 kg/ha) was recorded under treatment N3: 100 kg/ha which was statistically at par with treatment N2: 75 kg/ha. The probable reason for such a positive response due to addition of higher rate of nitrogen might be resulted in efficient photosynthesis and finally produced more seed yield. Higher supply of nitrogen sustained the uptake of nitrogen at later crop growth stages which improve vegetative and reproductive growth. Inadequate availability of nitrogen might have produced poor vegetative growth as well as reproductive growth which finally led to less seed yield. These results are analogous to those reported by Patel *et al.* (2009),Patel *et al.* (2010) and Man *et al.* (2017).

**Table 1**: **Effect of spacing and nitrogen on plant population, growth attributes, yield attributes**

 **and yield of castor (GAC 11)**

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Treatments** | **Plant population/ Net plot** | **Plant height (cm)** | **No. of branches /plant** | **No. of spikes/plant** | **Main spike length (cm)** | **No. of capsule/main spike** | **Seed yield (kg/ha)** | **Seed index** |
| **Main plot : Spacing (S)** |
| S1 : 60-120-60 cm (Paired row) | **46.5** | 89.6 | 4.07 | 5.30 | 53.4 | 61.1 | **1069** | 32.3 |
| S2 : 60-150-60 cm (Paired row) | 30.9 | 89.7 | 4.13 | 5.22 | 53.0 | 60.7 | 1023 | 32.5 |
| S3 : 60-180-60 cm (Paired row) | 30.7 | 87.9 | 3.92 | 5.18 | 52.3 | 60.5 | 991 | 32.3 |
| S4 : 180 x 60 cm (Farmer’s practice) | 22.9 | 85.3 | 3.98 | 5.11 | 50.8 | 60.4 | 871 | 32.3 |
| **S.Em±** | **0.123** | **1.49** | **0.081** | **0.101** | **0.888** | **1.15** | **20.4** | **0.317** |
| **C.D. at 5 %** | **0.365** | **NS** | **NS** | **NS** | **NS** | **NS** | **60.5** | **NS** |
| **C.V. (%)** | **1.95** | **8.79** | **10.4** | **10.0** | **8.81** | **9.82** | **10.7** | **5.09** |
| **Sub plot : Nitrogen levels(N)** |
| N1 : 50 kg/ha | 32.9 | 84.2 | 3.73 | 4.78 | 48.5 | 56.3 | 932 | 32.3 |
| N2 : 75 kg/ha | 32.6 | 89.2 | 4.08 | 5.33 | 53.6 | 62.0 | 1009 | 32.4 |
| N3 : 100 kg/ha | 32.8 | **91.0** | **4.27** | **5.51** | **55.1** | 63.8 | **1024** | 32.3 |
| **S.Em±** | **0.136** | **1.21** | **0.076** | **0.083** | **0.697** | **0.826** | **11.5** | **0.316** |
| **C.D. at 5 %** | **NS** | **3.43** | **0.216** | **0.237** | **1.98** | **2.35** | **32.6** | **NS** |
| **C.V. (%)** | **2.48** | **8.21** | **11.3** | **9.62** | **7.99** | **8.17** | **6.97** | **5.86** |
| **INTERACTION**  |
| **S X N** | **NS** | **NS** | **NS** | **NS** | **NS** | **NS** | **Sig.** | **NS** |

 Different soil parameters like, Organic carbon, Av. P2O5 ,Av. K2O, Soil pH and Soil EC were found non significant. This might be due to the recycling of nutrient from lower layer of soil profile due to deep root system of castor might have contributed for maintaining the available nutrient content in the soil.

**Table 2**: **Effect of spacing and nitrogen on soil parameters of castor (GAC 11)**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Treatments** | **Organic carbon (%)** | **Av. P2O5 (kg/ha)** | **Av. K2O (kg/ha)** | **PH** | **EC (dsm-1)** |
| **Main plot : Spacing (S)** |
| S1 : 60-120-60 cm (Paired row) | 0.88 | 53.1 | 800 | 8.22 | 0.48 |
| S2 : 60-150-60 cm (Paired row) | 0.86 | 51.7 | 802 | 8.06 | 0.49 |
| S3 : 60-180-60 cm (Paired row) | 0.86 | 53.3 | 819 | 8.09 | 0.46 |
| S4 : 180 x 60 cm (Farmer’s practice) | 0.86 | 53.4 | 821 | 8.13 | 0.49 |
| **S.Em±** | **0.011** | **1.04** | **7.42** | **0.046** | **0.01** |
| **C.D. at 5 %** | **NS** | **NS** | **NS** | **NS** | **NS** |
| **C.V. (%)** | **6.83** | **10.2** | **4.76** | **2.93** | **13.4** |
| **Sub plot : Nitrogen levels(N)** |
| N1 : 50 kg/ha | 0.85 | 53.4 | 808 | 8.15 | 0.48 |
| N2 : 75 kg/ha | 0.86 | 52.6 | 810 | 8.10 | 0.48 |
| N3 : 100 kg/ha | 0.89 | 52.8 | 814 | 8.13 | 0.47 |
| **S.Em±** | **0.014** | **1.08** | **8.15** | **0.044** | **0.010** |
| **C.D. at 5 %** | **NS** | **NS** | **NS** | **NS** | **NS** |
| **C.V. (%)** | **9.60** | **12.22** | **6.03** | **3.28** | **12.0** |
| **INTERACTION**  |
| **S X N** | **NS** | **NS** | **NS** | **NS** | **NS** |

**3.3. Interaction effects of spacing and nitrogen levels:**

 The interaction effects between spacing and nitrogen levels with respect to growth & yield attributes and soil parameters of castor was found non-significant. However, the interactions between spacing and nitrogen levels were found significant in pooled results with respect to seed yield of castor. Significantly the highest seed yield of castor was recorded under treatment S2N3 (60-150-60 cm, Paired row + 100 kg N/ha) which was statistically at par with treatment S1N1 (60-120-60 cm, Paired row + 50 kg N/ha), S1N2 (60-120-60 cm, Paired row + 75 kg N/ha), S1N3 (60-120-60 cm, Paired row + 100 kg N/ha), S2N2 (60-150-60 cm, Paired row + 75 kg N/ha), S3N3 (60-180-60 cm, Paired row + 100 kg N/ha). The findings are in accordance with the results reported by Narkhede *et al.* (1984) and Patel *et al.* (2010).

**Table 3**: **Interaction effect of row spacing and nitrogen on seed yield of castor (GAC 11)**

|  |  |  |  |
| --- | --- | --- | --- |
| **S X N** | **N1** | **N2** | **N3** |
| **S1** | 1054 | 1074 | 1080 |
| **S2** | 911 | 1077 | **1081** |
| **S3** | 936 | 999 | 1037 |
| **S4** | 829 | 886 | 898 |
| **S.Em±** | **23.0** |
| **C.D. at 5 %** | **65.3** |
| **C.V. (%)** | **8.83** |

**3.4 Economics**

 The results revealed that maximum net realization and BCR were recorded under treatments S1N2 (60-120-60 cm, Paired row + 75 kg N/ha), S1N3 (60-120-60 cm, Paired row + 100 kg N/ha), S2N2 (60-150-60 cm, Paired row + 75 kg N/ha) & S2N3 (60-120-60 cm, Paired row + 75 kg N/ha) while, low cost of cultivation was found under treatment S1N1 (60-120-60 cm, Paired row + 50 kg N/ha).

**Table 4**: **Effect of row spacing and nitrogen on economics of castor GAC 11)**

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Treatments** | **Yield (kg/ha)** | **Gross realization (Rs./ha** | **Treatment cost (Rs./ha** | **Common cost****(Rs./ha)** | **Total cost of cultivation (Rs./ha)** | **Net Realization (Rs./ha)** | **BCR** |
| S1N1 | 1054 | 74307 | **2327** | 55947 | **58274** | 16033 | 1.28 |
| S1N2 | 1074 | 75717 | 2705 | 55947 | 58652 | 17065 | 1.29 |
| S1N3 | 1080 | 76140 | 3082 | 55947 | 59029 | 17111 | 1.29 |
| S2N1 | 911 | 64226 | 2327 | 55947 | 58274 | 5951 | 1.10 |
| S2N2 | 1077 | 75929 | 2705 | 55947 | 58652 | 17277 | 1.29 |
| S2N3 | 1081 | 76211 | 3082 | 55947 | 59029 | 17181 | 1.29 |
| S3N1 | 936 | 65988 | 2327 | 55947 | 58274 | 7714 | 1.13 |
| S3N2 | 999 | 70430 | 2705 | 55947 | 58652 | 11778 | 1.20 |
| S3N3 | 1037 | 73109 | 3082 | 55947 | 59029 | 14079 | 1.24 |
| S4N1 | 829 | 58445 | 2327 | 55947 | 58274 | 170 | 1.00 |
| S4N2 | 886 | 62463 | 2705 | 55947 | 58652 | 3811 | 1.06 |
| S4N3 | 898 | 63309 | 3082 | 55947 | 59029 | 4280 | 1.07 |

**4. CONCLUSION**

 Looking to the above results of interactions between spacing and nitrogen with respect to seed yield of castor and cost of cultivation, castor (GAC 11) crop should be sown in paired row at the spacing of 60-120-60 cm and fertilize the crop with 5 t FYM/ha and 50 kg P2O5/ha as basal, while 50 kg N/ha should be applied in three splits i.e., 12.5 kg N/ha as a basal, 25 kg N/ha at 30 DAS and 12.5 kg N/ha at 60 DAS for getting better yield with low cost of cultivation on heavy lack soil of middle Gujarat (AES IX).

**Disclaimer (Artificial intelligence)**

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

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