

Effect of Drip Irrigation and Nitrogen Fertigation on Quality, Chemical Parameters, Yield and Economics of Semi *Rabi* Castor (*Ricinus communis* L.)

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Abstract A field was conducted during semi *rabi* 2013-14 and 2014-15 to find out a suitable irrigation scheduling and sources of nitrogen fertigation. The experiment comprised of four scheduling of irrigation (0.6 ADFPE, 0.8 ADFPE, 1.0 ADFPE through drip system and surface method and three nitrogen fertigation (N_1 : 50% RDN, N_2 : 75% RDN and N_3 : 100% RDN (i.e. 80 kg/ha), thereby making twelve treatment combinations. The result revealed that to achieve profitable yield from semi *rabi* castor, follow irrigation at 1.0 ADFPE through drip in conjunction with fertigation of nitrogen @ 60 kg/ha through urea in four equal

splits at 30, 60, 90 and 120 DAS, respectively. Additional 20 kg N/ha along with 40 kg P_2O_5 /ha need to be applied before sowing the crop.

Keywords IW: CPE ratio, Recommended dose of nitrogen, Water use efficiency, Nitrogen use efficiency.

Introduction

Castor (*Ricinus communis* L.) is non edible oil seed crop having high industrial importance due to presence of unique fatty acid and ricinoleic acid. The crop is grown mainly under irrigated condition. Castor is extensively cultivated in India, China, Brazil, Ethiopia, Thailand in the world. Drip irrigation system optimizes the irrigation water and puts it uniformly and directly to the root zone of the plants at frequent interval based on crop water requirement through a closed net work of low pressure plastic pipes. Superiority of drip system in terms of water saving and increased in yield along with other benefits over surface method of irrigation is proved by many research evidence. Drip irrigation system improves the WUE by increasing yield of cotton with limited quantity of water. Total area, production and productivity of castor crop in the world during 2011-12 were 20.06 lakh hectares, 18.77 lakh tonnes and 1070 kg/ha, respectively. In India total acreage, production and productivity of castor crop during 2011-12, were 11.20 lakh hectares, 15.80 lakh tonnes and 1240 kg/ha, respec-

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Table 1. Yield attributing characters and yield as influenced by different irrigation scheduling and nitrogen fertigation in semi *rabi* castor.

| Treatments | Plant height (cm) at harvest | Length of main spike (cm) | Seed yield (kg/ha) | Stalk yield (kg/ha) | Oil content (%) | Oil yield (kg/ha) | N-uptake by seed (kg/ha) | N-uptake in stalk (kg/ha) | Total N-uptake by crop (kg/ha) |
|---------------------------------|------------------------------|---------------------------|--------------------|---------------------|-----------------|-------------------|--------------------------|---------------------------|--------------------------------|
| Irrigation scheduling | | | | | | | | | |
| I ₁ : 0.6 ADFPE | 130.2 | 56.50 | 1998 | 2537 | 47.38 | 947 | 48.29 | 22.54 | 70.83 |
| I ₂ : 0.8 ADFPE | 143.2 | 60.63 | 2314 | 2831 | 47.66 | 1103 | 58.50 | 30.81 | 89.30 |
| I ₃ : 1.0 ADFPE | 149.6 | 65.91 | 2553 | 3024 | 48.19 | 1232 | 72.40 | 36.08 | 108.48 |
| I ₄ : Surface method | 139.9 | 54.57 | 2062 | 2476 | 47.13 | 969 | 49.55 | 20.63 | 70.17 |
| SEm± | 2.8 | 1.25 | 58 | 53 | 0.65 | 26 | 1.99 | 1.85 | 2.77 |
| CD (<i>p</i> =0.05) | 8.4 | 3.72 | 171 | 158 | NS | 78 | 5.9 | 8.37 | 8.23 |
| CV % | 9.8 | 10.32 | 12.70 | 9.61 | 6.64 | 12.12 | 17.04 | 17.74 | 16.03 |
| Nitrogen fertigation (N) | | | | | | | | | |
| N ₁ : 50% RDN | 135.4 | 56.36 | 2008 | 2595 | 47.08 | 945 | 48.11 | 24.65 | 72.75 |
| N ₂ : 75% RDN | 141.6 | 58.42 | 2239 | 2723 | 47.66 | 1066 | 57.55 | 27.20 | 84.75 |
| N ₃ : 100% RDN | 145.1 | 63.42 | 2448 | 2834 | 48.04 | 1177 | 65.90 | 30.69 | 96.59 |
| SEm ± | 1.7 | 0.98 | 40 | 38.89 | 0.43 | 21 | 1.19 | 0.69 | 1.57 |
| CD (<i>p</i> =0.05) | 4.7 | 2.81 | 115 | 110.56 | NS | 60 | 3.38 | 1.96 | 4.47 |
| Interaction | | | | | | | | | |
| I × N | NS | NS | NS | NS | NS | NS | NS | Sig. | Sig. |
| CV % | 6.7 | 9.40 | 10.25 | 8.08 | 5.20 | 11.28 | 11.78 | 1424 | 10.52 |

tively [1]. The contribution of India in the world is 56% in acreage and 84% in production of castor. Thus, India is leading country in the world not only in acreage and production but in productivity of castor also. In India, during last decade area, production and productivity were increased to 37, 59 and 35%, respectively. Further, Gujarat occupying area, production and productivity of castor crop were 4.22 lakh ha, 8.33 lakh MT and 1972 kg/ha, respectively [2].

Materials and Methods

An experiment was conducted at Agronomy Instructional Farm, Chimanbhai Patel College of Agriculture, Sardarkrushinagar Dantiwada Agricultural University, Sardarkrushinagar, district: Banaskantha (North Gujarat) to study effect of drip irrigation and nitrogen fertigation on quality, chemical parameters, yield and economics of semi *rabi* castor (*Ricinus communis* L.) during 2013-14 and 2014-15.

The experiment was comprised of four schedules of irrigation (0.6 ADFPE, 0.8 ADFPE, 1.0 ADFPE

through drip system and surface method) and three levels of nitrogen fertigation (N₁: 50% RDN, N₂: 75% RDN and N₃: 100% RDN (i.e. 80 kg/ha), thereby making twelve treatment combinations. The field was laid out in split plot design with four replications. Castor variety GCH 7 was used as a test crop. The soil of experimental field was loamy sand having good drainage capacity. It was low in organic carbon (0.27%) and available nitrogen (161 kg/ha), medium in available phosphorus (36.7 kg/ha) but sulfur (10.51 ppm) but high in available potash (284 kg/ha). This zone is characterized by semi-arid climate with extreme cold winter and hot and dry windy summer. Generally, monsoon commences in the middle of June and retreats by the middle of September, most of the precipitation is received from the South-West monsoon, concentrating in the month of July and August. The annual average rainfall is about 638 mm in 26 rainy days (1981–2010). The winter season is fairly cold and dry starts from the end of October and continues till the end of February. The minimum temperature of the year reached in the months of December or January. The temperature starts rising from February and reaches

Table 2. N-uptake by stalk as influenced due to I × N interaction in pooled basis in semi *rabi* castor.

| Treatments | N-uptake by stalk (%) | | |
|---------------------------------|----------------------------|----------------------------|-----------------------------|
| | Nitrogen fertigation (N) | | |
| | N ₁ :50% RDN | N ₂ :75% RDN | N ₃ :100% RDN |
| Irrigation schedules (I) | | | |
| I ₁ : 0.6 ADFPE | 19.95 | 23.25 | 24.42 |
| I ₂ : 0.8 ADFPE | 27.54 | 30.05 | 34.82 |
| I ₃ : 1.0 ADFPE | 29.62 | 35.08 | 43.52 |
| I ₄ : Surface method | 21.46 | 20.40 | 20.01 |
| SEm ± | | 1.385 | |
| CD (<i>p</i> =0.05) | | 3.938 | |
| CV % | | 14.24 | |

the maximum in the months of April or May. The wind velocity is very high during summer. The annual rainfall was 1109 mm with 39 rainy days during 2013-14 and annual rainfall of 550 mm received in 23 rainy days during 2014-15.

The field was laid out in split plot design with four replications. The experiment was comprised of four schedules of irrigation (0.6 ADFPE, 0.8 ADFPE, 1.0 ADFPE through drip system and surface method) and three levels of nitrogen fertigation (N₁ : 50% RDN, N₂ : 75% RDN and N₃ : 100% RDN (i.e. 80 kg/ha), thereby making twelve treatment combinations. Scheduling of irrigation for drip system was maintained by considering the evapotranspiration. The quantity of water delivered per dripper at different places were measured and average volume was utilized calculating the quantity of water to be delivered and time of operation as per treatments at every alternate day for the drip system. In surface method irrigation was given at 0.8 IW : CPE ratio with 60 mm depth. Recommended dose of fertilizer was 80-25-00 kg NPK/ha. Application of 25% RDN and full dose of phosphorus was given at basal and rest 75% RDN in four equal splits at 30, 60, 90 and 120 DAS as per treatments.

Soil samples were collected prior to start of experiment and after completion of the experiment from

Table 3. Total N-uptake by crop as influenced due to I × N on pooled basis in semi *rabi* castor.

| Treatments | Nitrogen fertigation (N) | | |
|---------------------------------|----------------------------|----------------------------|-----------------------------|
| | N ₁ :50% RDN | N ₂ :75% RDN | N ₃ :100% RDN |
| Irrigation schedules (I) | | | |
| I ₁ : 0.6 ADFPE | 59.01 | 73.41 | 80.04 |
| I ₂ : 0.8 ADFPE | 77.15 | 89.01 | 101.75 |
| I ₃ : 1.0 ADFPE | 89.65 | 106.18 | 129.59 |
| I ₄ : Surface method | 65.16 | 70.35 | 74.99 |
| SEm ± | | 3.151 | |
| CD (<i>p</i> =0.05) | | 8.96 | |
| CV % | | 10.52 | |

0 to 15 cm depth for analysis of available N. The soil was also analysed for pH and electrical conductivity for 0–15 cm depth. Treatment wise balance sheet of NPK indicating the available nutrients in the soil at initial stage, nutrients added for raising the crop, nutrient uptake by the crop, nutrient left in the soil after the harvesting, actual grain/loss over initial status and apparent nutrients balance in the soil were worked out. The economics of different treatments was calculated by taking into account the various inputs required and outputs realized as per the prevailing cost of inputs and outputs during the respective years. All the data obtained were statistically analyzed using the *F*-test procedure for split plot design. The critical differences for comparing treatment means were worked out at 5% level of significance. The trends of the results was similar during analysis for results and comparison.

Results and Discussion

Effect of irrigation schedules

Effect on growth and yield parameters

Plant height was significantly increased under irrigation treatment I₃ than I₁ and I₄ at harvest of the crop (Table 1). Treatment I₃ (1.0 ADFPE) of drip irrigation

Table 4. Economics as influenced by irrigation schedules and nitrogen fertigation in semi *rabi* castor on pooled data basis. Selling price of castor seed: Rs 38.5/kg, Selling price of castor stalk: Rs 0.50/kg.

| Treatments | Yield (kg/ha) | | Gross realization (Rs/ha) | | | Cost of cultivation (Rs/ha) | Net realization (Rs/ha) | BCR |
|---------------------------------|---------------|-------|---------------------------|-------|-------|-----------------------------|-------------------------|------|
| | Seed | Stalk | Seed | Stalk | Total | | | |
| Irrigation schedules (I) | | | | | | | | |
| I ₁ : 0.6 ADFPE | 1998 | 2537 | 76923 | 1269 | 78192 | 30609 | 47583 | 2.55 |
| I ₂ : 0.8 ADFPE | 2313 | 2831 | 89051 | 1416 | 90467 | 32254 | 58212 | 2.80 |
| I ₃ : 1.0 ADFPE | 2552 | 3024 | 98252 | 1512 | 99764 | 33611 | 66153 | 2.97 |
| I ₄ : Surface method | 2062 | 2475 | 79387 | 1238 | 80625 | 34362 | 46263 | 2.35 |
| Nitrogen fertigation (N) | | | | | | | | |
| N ₁ : 50% RDN | 2007 | 2595 | 77270 | 1298 | 78568 | 31606 | 46962 | 2.49 |
| N ₂ : 75% RDN | 2239 | 2722 | 86202 | 1361 | 87563 | 32728 | 54836 | 2.68 |
| N ₃ : 100% RDN | 2448 | 2834 | 94248 | 1417 | 95665 | 33794 | 61871 | 2.83 |

produced higher length of main spike. It might be due to drip irrigation at higher fraction improved soil moisture status around the root zone and increased the nutrients availability ultimately resulted in to growth and yield attributing characters. These findings are in accordance with those reported by Nagabhushanam and Raghavaiah [3] and Nagar and Patel [4].

Effect on yields

A perusal of data indicated that seed yield of castor plant significantly increased with increase in levels of drip irrigation schedules from treatment I₁ (0.6 ADFPE) to treatment I₃ (1.0 ADFPE) during the years 2013-14, 2014-15 and on pooled basis. Significantly the highest seed yield of 273.3 g/plant was obtained with drip irrigation schedules treatment I₃ (1.0 ADFPE) in pooled analysis. Treatment I₄ (surface method) and I₁ (0.6 ADFPE) recording lower values found equally effective.

All the yield attributes studied during the course of investigation were closely associated with the growth attributes. Significantly the highest seed yield (2,553 kg/ha) was obtained under drip irrigation treatment at 1.0 ADFPE (I₃), while significantly the lowest seed yield was noticed under irrigation level I₁ (1,998 kg/ha) on pooled basis but it remained at par with irrigation level I₄ (surface method). The magnitude of increase in seed yield under treatment I₃ (1.0 ADFPE)

was to the extent of 9.36 and 21.73 and 19.23% over treatment I₂ (0.8 ADFPE), I₁ (0.6 ADFPE) and I₄ (surface method) on pooled basis, respectively. The increase in seed yield might be due to the effect of timely and frequent irrigation under drip irrigation treatments I₃ (1.0 ADFPE) provided constant wet root zone, increased the nutrients availability enhanced growth, yield attributes and ultimately higher seed yield. The simple correlation study also indicated that there was close association of almost all growth and yield attributes and chemical parameters with seed yield. These results are in close conformity with those reported by Reddy et al. [5] in castor.

An appraisal of data revealed significant differences in stalk yield found due to irrigation schedules levels during the years 2013-14, 2014-15 and on pooled basis analysis. Treatment I₃ (irrigation schedules at 1.0 ADFPE) ranked at top registering stalk yield of 2946 and 3102 during 2013-14 and 2014-15, while on pooled basis, I₃ (irrigation schedules at 1.0 ADFPE) recorded significantly the highest stalk yield. Higher stalk yield obtained under I₃ is contributed to increase in N uptake by stalk during both the years and on pooled basis.

Effect on quality parameter

The results in respect of oil content in seed indicated that there was non-significant difference observed

among the irrigation treatments. But with regard to oil yield, drip irrigation treatment I_3 (1.0 ADFPE) recorded significantly the highest oil yield as compared to rest of the treatments.

Effect on chemical parameters

N-uptake in seed, stalk and total by crop was found significant due to different irrigation treatments (Table 2). Drip irrigation treatment I_3 (1.0 ADFPE) exhibited significant superiority with respect to N-uptake in seed, stalk and total by crop which was to the tune of 72.40, 36.08 and 108/48 kg/ha as compared to treatments I_2 (0.8 ADFPE) and I_1 (0.6 ADFPE), I_4 (surface method), respectively. Balance of nutrients in the soil is the difference between the total nutrients initially available in the soil along with applied and the amount that has been removed by the crop, assuming the losses that was constant. The important factor affecting carryover of different nutrients are soil characteristics, weather conditions, amount and types of manures and fertilizers applied, time and method of their application, yield response and handling of crop. The pooled results pertaining to post harvest available soil nitrogen status differed non-significantly due to different levels of irrigation.

Effect of nitrogen fertigation

Effect on growth and yield parameters

In the present investigation, application of 100% recommended dose of nitrogen (RDN) recorded significantly higher values of plant height at harvest and length of main spike (Table 1). Nitrogen is the primary essential element for growth, development and yield of castor crop. Superior vegetative growth due to increase in dose of nitrogen fertilizer as realized in the present investigation would obviously improve the yield attributes.

Effect on yields

Seed yield per plant was significantly influenced by different nitrogen fertigation treatments during the years 2013-14, 2014-15 and in pooled data. Significantly the highest seed yield of 263.74 g/plant was

obtained with an application of 100% RDN through fertigation (N_3) in pooled results, respectively. While it was at par with N_2 (75% RD) during 2014-15. The results in respect of seed yield revealed that nitrogen level had pronounced effect on seed yield. Nitrogen application @ 100% RD (N_3) produced significantly the highest seed yield as compared to rest of the treatments. The increase in seed yield under treatment N_3 (100% RD) was to the extent of 8.54 and 17.97% over treatment N_2 (75% RD) and N_1 (50% RD) in pooled analysis, respectively. Drip fertigation, under some condition can produce comparable or higher yields with substantial savings up to 50% of N. It was observed from the data that stalk yield was significantly influenced by different nitrogen fertigation treatments. Significantly higher stalk yield of 2,834 kg/ha was obtained with an application of 100% RDN (N_3) which was at par with an application of 75% RDN (N_2). Significantly the lowest stalk yield of 2,595 kg/ha was observed under the treatment N_1 (50% RD) during pooled basis data.

Effect on quality parameters

Data indicated that oil content in seed and oil yield was significantly the highest with 100% RDN (N_3) as compared to the rest of the treatments. This also might be due to marked increase in seed yield under higher levels of N i.e. treatment N_3 (100% RD through fertigation) was directly responsible for higher oil yield.

Effect on chemical parameters

The results in respect of N-uptake in seed, stalk and total by the crop revealed that it was significantly influenced due to different nitrogen levels and maximum N-uptake in seed, stalk and by the crop were achieved under treatment N_3 (100% RD). The increase in N-uptake in seed and stalk under treatment N_3 (100% RD) might be due to production and conversion of more photosynthates needed for seed development. Besides, N fertilization increases the cation exchange capacity of plant root and thus makes them more efficient in absorbing nutrient ions. Higher N removal by castor under higher level of nitrogen i.e. treatment N_3 (100% RD) was probably due to higher seed and stalk yields, improved the chemical properties of soil, bet-

ter utilization of water, thereby enhanced seed yield led higher uptake of N. Moreover highly N uptake by the crop under N_3 is contributed to increase in growth, development, yield attributing and high seed yield. The results corroborate the reports of Maan and Amin [6].

Interaction effect of I × N

On the basis of pooled data, the treatment combination I_3N_3 (1.0 ADFPE with 100% RD through fertigation) showed superiority bearing the highest values of N-uptake by stalk and total N-uptake by crop (Table 2). Table 3 shows that treatment combination I_3N_3 (1.0 ADFPE with 100% RDN) registered significantly the highest N-uptake by stalk (43.52) during 2013-14 and in pooled results. Data showed that treatment combination I_3N_3 (1.0 ADFPE with 100% RDN) registered significantly higher total N-uptake by crop (129.59kg/ha) in pooled analysis, while lower total N-uptake by crop was recorded with treatment combination I_1N_1 (0.6 ADFPE with 50% RDN, 59.01 kg/ha) in pooled analysis.

Economics

Table 4 shows the economics influenced due to various irrigation schedules. The drip irrigation sched-

ules treatment I_3 (1.0 ADFPE) earned the highest net realization (Rs 66153/ha) along with BCR value of 2.97. This might be due to higher cost of inputs. Benefit cost analysis (Table 4) further showed that net realization/ha and BCR values increased with graded level of nitrogen fertigation. Treatment 100% RDN (N_3) accrued the highest net return of Rs 61871/ha. With the BCR value of (2.83). While the lowest BCR value (2.49) was observed under treatment N_1 (50% RDN).

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