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Research Paper

Determination of nutrient uptake and nutrient-use efficiency of drip-irrigated direct-seeded rice (*Oryza sativa*) genotypes at different fertigation schedules

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ABSTRACT

A field experiment was conducted at Gangavathi, Karnataka, during the rainy (*kharif*) season of 2017 and 2018, to know the response of genotypes to nutrient management under drip irrigation in dry direct-seeded rice. The pooled mean of 2 years indicated that, drip fertigation with water-soluble nitrogen fertilizer (WSNF) in 8 splits at 10 days interval recorded 23% higher grain (5,197 kg/ha) and 20% higher straw yield (5,637 kg/ha) than soil application with 100% NPK fertilizer. 'GNV 10-89' variety recorded higher grain (5,244 kg/ha) and straw yield (5,696 kg/ha) than 'BPT 52-04'. Drip fertigation of WSNF applied in 8 splits at 10 days interval, recorded significantly higher nitrogen uptake (170.1 kg/ha) and nitrogen-use efficiency (34.6 kg/ha) than soil application with 100% NPK fertilizer.

Key words: Direct-seeded rice, Fertigation, Rice genotypes, Split application

In India, rice is grown on 42.94 million hectares, with an annual production of about 112.90 million tonnes and productivity of about 2,585 kg/ha (DAC, 2018). India is the second largest country for rice production and rice continues to hold the key to sustainable food production by contributing 20–25% of agriculture production and assures food security for more than half of the total population (DAC, 2012). In Karnataka, rice is cultivated in the command areas of Cauvery, Tungabhadra (TBP) and Upper Krishna where transplanting is the predominant method of establishment. In the Western Ghats and high-rainfall areas, the rice is cultivated as drill-sown rice. The total area under rice in Karnataka is 0.874 million ha, with an annual production of 2.359 million tonnes and with a productivity of 2,699 kg/ha (DAC, 2018).

In 19th century, high-yielding rice genotypes were developed only for transplanted rice. Because of erratic rainfall, the improper supply of water near command area and scarcity of water, direct-seeded rice is gaining importance and little is known about the yield potential and plant-type requirements under direct seeding. Promising research findings help to learn about the optimum schedule for fertigation and rice varieties with higher yield potential will help to make direct-seeding an important production system in the rice tract of Tungbadra command area. Direct-seeded rice (DSR) is one of the resource conservation technologies which requires less labour and tends to mature faster than transplanted crops (Chauhan and Johnson, 2012). Here, rice crop is not subjected to transplanting stress. Direct seeding can be done in 2 ways, depending on the land-preparation method used such as dry seeding and wet seeding. Dry seeding is done for rainfed and deepwater ecosystems in which sowing is done in dry soil surface. In the case of wet seeding, sowing is done either through broadcast or drilling seeds into the mud with drum seeders in wet fields. In many countries where labour is limited and labour cost is very high, in such condition DSR could be an alternative to transplanted puddled rice (TPR), as it consumes less irrigation water without any significant yield reduction, requires less labour as puddling and transplanting is completely avoided and can be highly mechanized. The DSR is also reported to enhance nitrogen-use efficiency (NUE) and so can have low emission of greenhouse gases. Water becomes a scarce resource due to increased demand for industrial, agricultural and domestic purposes,

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besides increased cost on fertilizer necessitated for development and adoption of alternative agro-techniques which help in effective and efficient utilization of these inputs. In this context, micro-irrigation techniques and fertigation is the only way to manage water and nutrient resources efficiently.

Greater N-use efficiency in rice can be achieved by using water-soluble N sources with suitable varieties, improving timing and application methods and better incorporation of basal N fertilizer application without standing water. Split application of N has been reported to be the best method to improve N use efficiency, reduce denitrification losses, synchronize with plant demand and improve N uptake, straw and grain yield, and harvest index in DSR. Keeping these points in view, the present investigation was undertaken to assess the response of rice varieties to split applications of nitrogen under direct-seeded rice.

MATERIALS AND METHODS

The field experiment site was located in Northern Dry Zone (Zone-3) of Karnataka State (Semi arid eco sub region) at 15^{o} 35' 07'' N and 76^{o} 15' 47'' E at Agricultural Research Station (ARS), Gangavathi, University of Agricultural Sciences (UAS), Raichur, Karnataka. The monthly meteorological data of 2017 and 2018 were collected from the meteorological observatory located at ARS, Gangavathi. During the cropping period, total rainfall received was 453.2 mm in 2017 and 328.2 mm in 2018. In 2017, June and August months received the highest rainfall (159.7 and 197.6 mm, respectively) and May month received the highest rainfall in 2018 (107.9 mm). The experiment was laid out in Split-Plot design with 3 replications during the rainy season of 2017 and 2018. Main-Plot treatments consisted of 4 irrigation levels, i.e. S_1; Drip fertigation with WSNF in 3 splits (25 days interval) with basal P and K; S_2; drip fertigation with WSNF in 6 splits with basal P, K (15 days interval), S_3; drip fertigation with WSNF in 8 splits with basal P, K (10 days interval) and S_4; soil application of 100% NPK. Subplot treatments consisted of 3 genotypes, viz., G_1; 'GGV-05-01' (Gangvathi sona); G_2; 'GNV 10-89'; G_3; 'BPT 52-04'.

The line sowing was taken up on 30th August during 2017 and on 24th August during 2018, manually maintaining 20 cm row-to-row spacing using a seed rate of 35 kg / ha. Immediately after sowing, the seeds were covered with soil and manual irrigation was given. Third day after sowing of DSR, pre-emergent application of pendimethalin 38.7% CS @ 750 g a.i./ha was sprayed on moist soil. This was followed by post-emergent application of bispyribac sodium 10% SL @ 25 g a.i./ha at 20 days after sowing. Subsequently, 1 hand-weeding was carried out at 60 days after sowing (DAS) to control weeds. Water-soluble fertilizers were applied in the form of mono-ammonium phosphate, 0 : 0 : 50 used for basal dose and calcium nitrate used for top-dress. Similarly, conventional fertilizers like 17 : 17 : 17 and urea used, respectively, for supplying nitrogen, phosphorus and potassium at the rate of 150: 60: 50 kg/ha. 1.0% the $FeSO_4$ was sprayed to correct iron deficiency @ 20 and 30 DAS. Fertigation was done through the ventury system as per the treatment details. The fertigation schedule was started 2 weeks after sowing. Out of total nutrients, the entire dose of P and K were applied as basal dose and N was fertigated in 3, 6, 8 equal splits at 25, 15, 10 days interval. Micronutrient spray was also given uniformly.The crop was harvested when the ears turned brownish coupled with straw turning to yellowish colour. All the 3 genotypes used in this experiment were harvested at different days as they mature at differently. In 2018 and 2019, 'GNV 10-89' on 5th and 2nd January, 'GGV-05-01' on 19th and 15th January and 'BPT 52-04' on 3rd February and 28th January, respectively. Plot-wise yields were recorded. The data recorded at different stages of crop were subjected to statistical analysis at 5% probability.

RESULTS AND DISCUSSION

Grain yield and straw yield

Drip fertigation with WSNF in 8 splits at 10-day intervals recorded 23% higher grain and straw yield than soil application with 100% NPK fertilizer. Lowest grain and straw yields were recorded with soil application of 100% NPK fertilizer (Table 1). The higher grain yield when nitrogen was applied in 8 split was owing to production of more number of panicle per unit area, more filled grains/panicle, higher filling percentage and test weight. The fertigation schedule of N applied in 8 splits recorded better growth parameters like production of more tillers, higher leaf-area, leaf area index and higher dry-matter accumulation which are pre-requisites for improved yield parameters. Split application of N helped in better translocation of photosynthates from vegetative part to developing spikelets resulting in higher grain yield. Higher grain yield observed in the case of nitrogen applied in 8 splits might also owing better uptake of N, P and K by the plant that leads to higher photosynthetic rate and efficient utilization of nitrogen for the production of grains.

Split application of WSNF had higher concentration of available plant N increased the grain and straw yields and it could be owing efficient N uptake by plants that led to better photosynthetic rate and effective utilization of nitrogen at critical stages of crop and enhanced the growth parameters like plant height, tillers number, leaf area and total dry matter which in turn enhance the yield parameters. The results confirm the findings of Hafeez *et al.* (2013); Amrutha *et al.* (2016); Sangeetha (2019).

'GNV 10-89' gave higher grain and straw yield. The lowest grain and straw yields were noticed in 'BPT 52-04' (Table 1). The higher grain and straw yields recorded with 'GNV 10-89' might be owing to higher plant height, more tillers, more leaf area and higher panicle weight, higher panicle length, test weight and more filled grains. This indicated that 'GNV 10-89' expressed better growth and yield parameters and grain yield under drip fertigation than 'BPT 52-04'. Further, 'GNV 10-89' a short-duration variety being early by 15–20 days as compared to 'BPT 52-04', is well suitable under moisture-constraint situations to make the best use of the scarce moisture and the available season, and this cultivar facilitates early sowing of the second crop in succession because of an early harvesting. Our findings confirm those of Awan *et al*. (2011); Ramachandra *et al.* (2015); Mohinder (2016) and Sangeetha (2019)

Nutrient uptake

Among the fertigation schedules, drip fertigation of WSNF applied in 8 splits at 10 days interval, recorded significantly higher N, P and K uptake than soil application with 100% NPK fertilizer and also over drip fertigation of WSNF applied in 3 splits at 25 days interval but it was on par with drip fertigation of WSNF applied in 6 splits at 15 days interval (Table 2). Nitrogen applied through fertigation in 8 splits along with optimum moisture condition ensured effective availability of N throughout the crop growth period leading to higher N uptake. Similarly, greater uptake of N was attributed to increased growth parameters and grain yield. Since, nitrogen is supplied through fertigation, losses of applied nitrogen might be reduced as conditions are not favourable for percolation and leaching losses. Split application of WSNF was due to better availability of nutrients and water in the root zone as a result of frequent fertigation scheduling at lesser intervals which in turn resulted in better root activity as indicated by increased root volume and root weight. Thus, there was an increased concentration of these nutrients in grain and straw and the availability of sufficient quantities of nutrients during the critical stages of crop growth, less fixation of nutrient in the clay mineral, which resulted in better uptake of nitrogen and its better accumulation in the plant tissues. These results confirm the findings of Singh and Tripathi (2007) and Anusha (2015).

Among different genotypes on pooled data basis, significantly higher N, P and K uptake was recorded with 'GNV 10-89' compared to 'BPT 52-04' but it was on par with 'GGV 05-01' (Table 2). In the present investigation, 'GNV 10-89', produces good root system resulted into 31.1%, 50.1% and 24.5% higher nitrogen, phosphorus and potassium uptake, respectively as compared to 'BPT 52-04'. These results are in line with Yadav (2016).

Nutrient use efficiency

Nutrient use efficiency was varied significantly due to various fertigation schedules (Table 2). Drip fertigation of WSNF applied in 8 splits at 10 days interval recorded higher nutrient use efficiencies, viz., nitrogen use efficiency (NUE), phosphorus use efficiency (PUE) and potassium use efficiency (KUE) in pooled data, which was on par with drip fertigation of WSNF applied in 6 splits at 15 days interval but was significantly superior to soil application with 100 % NPK fertilizer and also over drip fertigation of WSNF applied in 3 splits at 25 days interval (Table 2). Nutrient use efficiency by various rice genotypes also differed significantly on the pooled basis. 'GNV 10-89', recorded significantly higher NUE, PUE and KUE than 'BPT 52-04', but it was on par with 'GGV 05-01', (Table 2). There was no significant difference among the treatment combinations of fertigation schedules and rice

Table 1. Grain and straw yield and harvest index as influenced by fertigation schedules and genotypes under drip irrigation in dry direct seeded rice (pooled data of 2 years)

Treatment	Grain yield (kg/ha)	Straw yield (kg/ha)	Harvest index
Main plots: Fertigation schedules (S)			
S_1, WSNF in 3 splits with basal P, K (25 days interval)	4,640	5,238	0.46
S_2, WSNF in 6 splits (15 days interval)	5,005	5553	0.46
S_3, WSNF in 8 splits with basal P, K (10 days interval)	5,197	5,637	0.47
S_4, Soil application with 100% NPK fertilizer	4,199	4,710	0.46
SEm±	109	97	0.01
CD (P=0.05)	378	336	NS
Sub plots:Genotypes (G)			
G_1, 'GGV 05–01'	4,918	5,485	0.46
G_2, 'GNV 10–89'	5,244	5,696	0.47
G_3, 'BPT 52-04'	4,118	4,672	0.46
SEm±	95	98	0.01
CD (P=0.05)	285	294	NS

genotypes. Increase in the nutrient use efficiency is mainly due to supplying the required quantity of nitrogen, phosphorus and potassium in early stage of crop growing period leads to promoting tiller and leaf area and at later stages supplying the small amount of nitrogen in split doses might have resulted in reduced losses of applied nitrogen through leaching, volatilization and surface runoff leading to increased nitrogen use efficiency in the case of fertigation of WSNF in 8 split. These results confirm those of Amrutha *et al*. (2016) and Dahiphale *et al*. (2017). Among genotypes, 'GNV 10-89' produced higher root length, root volume and favours lateral root branching in DSR with drip fertigation this might be due to the nature of genotypes and also helps in better utilization of available nutrients and produced a higher yield of crop per kg of applied nutrient thereby increase the NUE. Sangeetha (2019) also reported that variety 'GGV-05-01' has recorded higher NUE as compared to 'BPT 52-04'.

Economics

The fixed cost of drip system is equally divided into ten equal instalments as using that the system will serve for at least ten years. Among the fertigation schedules, lower cost of cultivation registered in soil application with 100% NPK fertilizer and where as irrespective of splits 100% WSNF registered higher cost of cultivation (Table 3). Among the genotypes, 'BPT 52-04' recorded higher cost of cultivation followed by 'GGV 05-01' and 'GNV 10-89' next in order (Table 3). Among the genotypes variation in cost of cultivation may be due to its variation in cost of seeds. Higher the cost of cultivation in 100% WSNF irrespective of splits due to the cost of water soluble fertilizer is very high compared to conventional fertilizers. The findings are in conformity with Anusha (2015).

Among the fertigation schedules, significantly higher gross returns was recorded with drip fertigation with WSNF in 8 splits with 10 days interval which was statistically at par with drip fertigation with WSNF in 6 splits with 15 days interval. Significantly lower gross return was recorded in soil application with 100% NPK fertilizer on pooled data basis and also drip fertigation with WSNF in 3 splits with basal P, K (Table 3). The pooled gross returns were significantly higher in 'GNV 10-89' and it was on par with 'GGV 05-01' and 'BPT 52-04' recorded significantly least gross return (Table 3). Within genotypes, variation in the gross returns it mainly because of difference in market price of particular genotypes as well as the yield difference. The results are in conformity with Naveen (2014); Mohinder (2016) and Sangeetha (2019).

Higher net returns and B:C ratio were recorded in soil application with 100% NPK fertilizer as compared to all fertigation schedules through drip. Among the fertigation schedules, drip fertigation of WSNF applied in 8 splits at 10 days interval recorded significantly higher net return and B:C ratio on pooled data basis and it was found at par with drip fertigation of WSNF applied in 6 splits at 15 days interval but was superior to drip fertigation of WSNF applied in 3 splits at 25 days interval (Table 3). Among the rice genotypes significantly higher net returns and B:C ratio noticed in 'GNV 10-89' it was on par with 'GGV 05-01'. However, significantly least net returns were observed in 'BPT 52-04' on pooled data basis (Table 3).

Drip fertigation of WSNF applied in 8 splits at 10 days interval recorded the 22.7% and 12.0% higher grain yield

Table 2. Nutrient uptake and nutrient use efficiency as influenced by fertigation schedules and genotypes under drip irrigation in dry direct seeded rice (pooled of 2 years)

Treatment	Nitrogen (kg/ha)	Phosphorus (kg/ha)	Potassium (kg/ha)	NUE (kg grain/ kg N)	PUE (kg grain/kg P)	KUE (kg grain/kg K)
Main plots: Fertigation schedules (S)						
S_1, WSNF in 3 splits with basal P, K (25 days interval)	146.2	21.0	137.5	30.9	77.3	92.8
S_2, WSNF in 6 splits (15 days interval)	161.8	24.1	146.2	33.4	83.4	100.1
S_3, WSNF in 8 splits with basal P, K (10 days interval)	170.1	25.6	153.6	34.6	86.6	103.9
S_4, Soil application with 100% NPK fertilizer	136.3	16.9	128.3	28.0	70.0	84.0
SEm±	5.8	1.0	3.9	0.7	2.3	2.5
CD (P=0.05)	20.0	3.4	13.6	2.5	8.0	8.7
Sub plots:Genotypes (G)						
G_1, 'GGV 05–01'	158.3	23.5	145.2	32.8	82.0	98.4
G_2, 'GNV 10–89'	171.6	26.1	154.7	35.0	87.4	104.9
G_3, 'BPT 52-04'	130.9	16.1	124.3	27.5	68.6	82.4
SEm±	4.6	0.9	3.3	0.7	1.8	2.2
CD (P=0.05)	13.8	2.7	9.9	2.2	5.5	6.6

NUE, Nitrogen-use efficiency; PUE, phosphorus-use efficiency; KUE, potassium-use efficiency

Table 3. Cost of cultivation, gross returns, net returns and B:C ratio as influenced by fertigation schedules and genotypes under drip irrigation in dry direct seeded rice (pooled data of 2 years)

Treatment	Cost of cultivation (×10³₹/ha)	Gross returns (×10³₹/ha)	Net returns (×10³₹/ha)	Benefit: cost ratio
Main plots: Fertigation schedules (S)				
S_1, WSNF in 3 splits with basal P, K (25 days interval)	78.9	95.1	16.1	1.19
S_2, WSNF in 6 splits (15 days interval)	78.9	102.5	23.6	1.30
S_3, WSNF in 8 splits with basal P, K (10 days interval)	78.9	106.5	27.5	1.35
S_4, Soil application with 100% NPK fertilizer	46.1	86.1	39.9	1.87
SEm±	-	2.1	2.1	0.04
CD (P=0.05)	-	7.3	7.4	0.14
Sub plots: Genotypes (G)				
G_1, GGV 05–01	70.7	102.6	31.9	1.51
G_2, GNV 10–89	70.6	104.1	33.4	1.53
G_3, BPT 52-04	70.8	85.9	15.1	1.25
SEm±	–	1.8	1.8	0.03
CD (P=0.05)	–	5.6	5.6	0.09

as compared to soil application with 100% NPK fertilizers and drip fertigation of WSNF applied in 3 splits at 25 days interval. Variety 'GNV 10-89', recorded 27.3% higher grain and 21.9% higher straw yield as compared to 'BPT 52-04'. In the present investigation drip fertigation of WSNF applied in eight splits at 10 days interval accounting 16.2% and 16.3% greater N uptake, 49.4% and 21.9% enhanced P uptake and 19.7% and 11.7% K uptake resulted into higher nutrient use efficiency as compared to soil application with 100% NPK fertilizers as well as drip fertigation of WSNF applied in 3 splits at 25 days interval. Further investigation needed on use the precision method for fergation scheduling and multi-location trail, on drip irrigation and fertigation. Even though water soluble nitrogen fertilizer applied in 6 splits at 15 DAS at 10 days interval recorded higher grain yield they are costly and hence, soil application of 100% NPK was found economically optimum under drip irrigation.

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