Nutrient and water use efficiency, nutrient uptake and Rice yield as influenced by fertigation levels and weed management practices

ABSTRACT

A field experiment was carried out at AICRP on Weed Management Research Farm, Department of Agronomy, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola during *kharif* 2020-21. Fertigation is the technique of supplying dissolved fertilizers to crops through an irrigation system. The experiment was laid out in split plot design with three replications and twenty treatment combinations having four different fertigation levels and five weed management practices. The results revealed that, significantly maximum grain yield of rice (5103 kgha^{-1}), straw yield (7268 kgha^{-1}) and harvest index (41.25%) were found maximum at 125% RDNK level of fertigation in 5 splits than lower fertigation levels (75 and 100 per cent) and over conventional soil application of 100 per cent RDF. Nutrient use efficiency (NUE) was found better in lower drip fertigation level of 75 per cent recommended dose of N and K per ha as compared to conventional soil application of fertilizers. Among the herbicides, directed spray of Pretilachlor + Pyrazosulfuron Ethyl @ 0.615 a.i. kgha^{-1} PE *fb.* Bispyribac sodium @ 0.025 a.i kgha^{-1} at 25 DAS resulted in maximum rice grain yield (5231 kgha^{-1}) and also total nutrient uptake by crop and water use efficiency indicating the feasibility of using herbicides for effective weed management in rice and for enhancing NUE and WUE. The 125% RDNK through drip fertigation in 5 splits recorded maximum Gross Monetary returns (₹120353 ha^{-1}), Net Monetary Returns (₹72924) and B:C ratio (2.54), nutrient use efficiency and water use efficiency. The herbicidal treatment of Pretilachlor + Pyrazosulfuron Ethyl 0.615 kgha-1 PE fb. Bispyribac sodium 0.025 kgha^{-1} at 25 DAS registered maximum GMR (₹128755 ha^{-1}), NMR (₹81412ha^{-1}) and B:C ratio (2.72) among all herbicidal treatments, indicating the feasibility of using herbicides for effective weed management in rice.

Key Words: *Drip, Fertigation, Weed management practices, Nutrient uptake, Aerobic rice, WUE, Nutrient Use efficiency*

1.INTRODUCTION

"Rice (*Oryza sativa*) is the most important cereal food crop in the world. It is the staple food for more than half of the world's population. In India rice was grown on 46 mha with production of 104.99 mt in the year 2022-23" (Peng et al., 2012). [1]. "Rice develops well in water, but recent developments demonstrate that rice can also be grown in dry soils under non-flooded conditions called "Aerobic rice". Aerobic rice cultivation saves water input and increases water productivity by reducing water use during land preparation and limiting seepage, percolation and evaporation". (Peng *et al*., 2012). [1]. "Hence there

is a need to develop and popularize innovative water saving technologies to “produce more rice crop from every drop” for a given specific location. The injudicious use of irrigation water and improper weed management practices are the important reasons of low productivity of rice in India. Adoption of micro irrigation might help in increasing the irrigated area, productivity of crops and water use efficiency” (Sivanappan, 2004) [2]. Soman (2018) [3] reported that “drip-fertigation offers clear advantage for increasing the productivity of rice with low water consumption in drip irrigation as compared to flood. Fertigation system assures precise application of nutrients through use of water-soluble fertilizers which are made available at the root zone along with water for its direct absorption by the crop”. “Drip fertigation significantly influenced the growth, yield, water productivity and nutrient use efficiency (NUE) in aerobic rice” (Kombali *et al.,*2016).[4] In fertigation methods, fertilizer use efficiency can increased up to 80 to 90 per cent.

“Fertilizer application in wetland rice farming done manually through the soil application in split doses is imprecise and causes problems such as fluctuating nutrient supply and uneven fertilizer spread. This leads to various losses of nutrients under submerged cultivation. For effective weed management, improved weed control practices that include chemical weed control with newer formulations and herbicide mixtures and integrated cultivation need to be developed and refined” [26]. Malik *et al*. (2021) [5] reported “57 % losses respectively due to weeds in rice in India. An integrated approach is required for addressing these issues regarding to soil water-plant-nutrient management at the plant rooting zone. The technique of fertigation, the direct application of water and nutrients to plants through a drip irrigation system. Drip fertigation offers the scope to increase the productivity of crops per unit land, time and input use in crop production. Introduction of new herbicides, chemical weed control with pre-mix combination of herbicide may result in effective weed control in rice”. With this background, an effort was made to assess the suitability of split application of nutrients through fertigation and weed management practices on nutrient and water use efficiency, nutrient uptake and yield of Rice.

2. MATERIALS AND METHODS

“The experiment was laid out in split plot design with three replications with 20 treatment combinations having 4 different fertigation levels and 5 weed management practices. The main plot treatments comprised of different levels of fertilizer in five splits at 75%, 100% and 125% of recommended dose of N and K fertilizers given through fertigation, however P was applied as basal and these treatments were compared with drip irrigation with 100% soil application of fertilizers (N in 3 splits). Whereas, sub plot treatments comprised of five weed management practices viz., Pendimethalin 1.0 $kgha^{-1}$ PE *fb.* Bispyribac sodium 0.025 $kgha^{-1}$ at 25 DAS; Pretilachlor + Pyrazosulfuron Ethyl 0.615 $kgha^{-1}$ PE *fb.* Bispyribac sodium 0.025 $kgha^{-1}$ at 25 DAS; Pretilachlor 0.75 $kgha^{-1}$ PE *fb.* Bispyribac sodium 0.025 $kgha^{-1}$ at 25 DAS; farmer practices - 2 HW at 15–20 days interval after sowing *fb.* 2 hoeing and weedy check” [26].

"The soil of experimental field was medium deep vertisol, low in available nitrogen (170.41 kgha^{-1}), medium in phosphorus (18.94 kgha^{-1}) and organic carbon (0.42 %), rich in available potassium (360.41 kgha^{-1}) and slightly alkaline in reaction (7.65). The sowing of Rice variety *Avishkar* was done on 19th June, 2020 at recommended spacing. The experimental site was established with inline drip irrigation system (16 mm).. The distance between two emitter was 50 cm with dripper discharge of 4 lph/hr. The water was applied through drip irrigation on every alternate day based on cumulative pan evaporation and surface irrigation water was applied at 1.0 IW/CPE ratio at a depth of 6 cm. The drip irrigation water to be applied per plant was determined by the formula given" by Michael (2008) [6]. "The nitrogen was given through urea (46% N), phosphorus through single super phosphate (16% P2O5), and and potassium through murate of potash (60% K2O) The application of herbicide was done as per the treatments with manually operated knapsack sprayer attached with a flat fan nozzle. After calibrating the sprayer, water volume used was 700 l/ha. for pre-emergence and 500 l ha^{-1}. for post emergence herbicides. Water use efficiency was calculated as the ratio of yield of marketable yield to the seasonal water requirement of rice. The plants removed for dry matter study at harvest were used for estimation of nitrogen, phosphorus and potassium content" [7]. These plants were dried, and nitrogen, phosphorus and potassium content in plant and grain were estimated by Kjeldahl method, di-acid extract by vanado-molybdate yellow colour method (Piper, 1966) [7] and Flame photometer method respectively. Nutrient use efficiency was calculated by using following formula and expressed in per centage (Crasswell and Godwin, 1984).[8] Data on various parameters were analyzed by using statistical method of analysis of variance as per the standard procedure.

3. RESULTS AND DISCUSSION

3.1 Nutrient uptake

The uptake of nutrients by rice was differed significantly due to different fertilizer levels given through fertigation.(Table 1). The drip fertigation with 125% RDNK in 5 Splits recorded maximum uptake of nitrogen (133.93 kgha^{-1}), phosphorus (26.99 kgha^{-1}) and potassium (137.34 kgha^{-1}) which was found at par with drip fertigation of 100% RDNK in 5 Splits. The lowest uptake of 96.75 N kgha^{-1}, 19.25 P kgha^{-1} and 107.29 K kgha^{-1} was observed in drip irrigation with 100% RDF through soil application (N in 3 Splits). 125% RDNK showed 38.43, 40.21 and 28.01% more N, P and K uptake respectively than 100% RDF through conventional method of soil application. The higher available soil moisture was provided due to continuous water supply at alternate days under drip irrigation which led to higher availability of nutrients in the soil and thereby increased the nutrient uptake under drip fertigation levels in splits. The application of nitrogen and potassium through fertigation not only stimulated vegetative growth and foraging capacity of roots, but also enhanced the the absorption and translocation of more nutrients under higher drip fertigation levels. The reduced availability of nutrients at lower dose of fertigation resulted in lower uptake of nutrients by crop at lower doses of fertilizers (Table 1) Application of large quantity of fertilizers as a single dose in conventional method of soil application of fertilizers, resulted in higher volatilization losses of nutrients which leads to lower availability of nutrients during later growth stages of crop. Better nutrient uptake due to increased moisture and nutrient availability throughout the growth stages in a drip system. Hebbar et al. (2004) [9] reported similar findings. The uptake of nutrients by rice was differed significantly due to different weed management practices. The significantly maximum uptake of nitrogen (123.25 kgha^{-1}), phosphorus (24.68 kgha^{-1}) and potassium (129.94 kgha^{-1}) was found in farmers practice of 2 HW at 15-20 days interval after sowing *fb.*2 hoeing which was found at par with Pretilachlor + Pyrazosulfuron ethyl @ 0.615 a.i. kgha^{-1} PE fb. Bispyribac sodium @ 0.025 a.i. kgha^{-1} at 25 DAS with N-P-K 120.31 N kgha^{-1}, 24.40 P kgha^{-1} and 125.91 K kgha^{-1}). Among herbicidal treatments application of Pretilachlor + Pyrazosulfuron ethyl @ 0.615 a.i. kgha^{-1} PE *fb.* Bispyribac sodium @ 0.025 a.i. kgha^{-1} at 25 DAS showed 30.70, 31.04 and 23.32% more N, P and K uptake respectively than weedy check. This could be attributed to less crop-weed competition favorably influencing development and a better soil environment, which resulted in increased soil nutrient mineralization and, as a result, an increase in residual soil nutrient status following rice crop harvest. Similar findings are given by Sunil *et al*. (2010) [10] Patel *et al*. (2018) [11], Saravanane *et al*. (2020) [12].

3.2 Water use efficiency

In the present study , the different drip fertigation levels significantly influenced the rice grain yield and water use efficiency. The highest WUE of 4.14 kgha^{-1} mm was registered under drip fertigation with 125% RDNK in 5 Splits followed by 3.86 kgha^{-1} mm in drip fertigation with 100% RDNK in 5 Splits. However, the lowest water use efficiency of 3.69 kgha^{-1} mm in drip irrigation with 100% RDF through soil application. Recommended dose of N and K registered 12.19 % more WUE than 100% RDF through soil application. In

case of drip fertigation with 125% RDNK in 5 splits, the amount of carbon assimilated as biomass or grain produced per unit of water used by the rice crop was more resulted in increased the WUE. As in drip fertigation with 125% RDNK in 5 Splits the rice grain yield was the highest one, for that the WUE was maximum in that treatment which was significant than the drip irrigation with 100% RDF soil application (N in 3 Splits) where fertilizer was applied through soil application. This similar results were also earlier reported by Deshmukh and Katake (2005) [13], Jagadish *et al*. (2019)[14] and Ashrafi *et al*.(2020)[15]

The water use efficiency was higher in all other weed management practices than weedy check. The highest water use efficiency (4.37 kgha^{-1} mm) was recorded in farmer practices of 2 hand weeding at 15-20 days' interval after sowing *fb*. 2 hoeing followed by Pretilachlor + Pyrazosulfuron ethyl @ 0.615 a.i. kgha^{-1} PE fb. Bispyribac sodium @0.025 a.i. kgha^{-1} at 25 DAS with WUE of 4.24 kgha^{-1} mm and the lowest WUE was recorded in weedy check (2.74 kgha^{-1} mm). Among all herbicidal treatments application of Pretilachlor + Pyrazosulfuron ethyl @ 0.615 a.i. kgha^{-1} PE *fb*. Bispyribac sodium @ 0.025 a.i. kgha^{-1} at 25 DAS showed 54.74% more WUE than weedy check. The cultural and chemical methods of weed management recorded higher water use efficiency than weedy check, which might be due to less infestation of weeds in these treatments, which provide sufficient quantity of water for growth and development of rice crop. The similar results regards to WUE was reported by Kumaran *et al.* (2015) [16], Mishra *et al*. (2018) [17], Singh *et al.* (2018) [18], Ramesh and Rathika (2020) [19] .

3.3 Nutrient use efficiency

The data presented in Table 1 indicated that, the highest nutrient use efficiency of 23.67 was registered under drip fertigation with 75% RDNK in 5 Splits followed by drip fertigation with 100% RDNK in 5 Splits (19.83), Drip irrigation with 100% RDF soil application (18.63) and the lowest in drip fertigation with 125% RDNK in 5 Splits (17.91). Nutrient use efficiency at 75% RDNK was 37.68% more than 100% RDF through soil application. In case of drip fertigation there was efficient utilization and precise application of nutrients according to the nutritional requirements of the crop as compared to conventional soil application of fertilizers. Similar kind of result were reported by Modinat *et al*. (2014) [20].

The nutrient use efficiency was higher in all other weed management practices than weedy check. The highest NUE was recorded in farmer practices i.e. 2 HW at 15-20 days' interval after sowing *fb*. 2 hoeing (22.45 kgkg^{-1}) and the lowest NUE was recorded in weedy check treatment (12.41 kgkg^{-1}). Among all herbicidal treatments application of Pretilachlor + Pyrazosulfuron ethyl @ 0.615 a.i. kgha^{-1} PE fb. Bispyribac sodium @ 0.025 a.i. kgha^{-1} at 25 DAS showed 75.66% more NUE than weedy check. In case of Pretilachlor + Pyrazosulfuron ethyl @ 0.615 a.i. kgha^{-1} PE fb. Bispyribac sodium @ 0.025 a.i. kgha^{-1} at 25 DAS), higher rice grain yield was obtained rather than other herbicidal applied treatments so NUE was maximum in this treatment after farmer practices i.e. 2 HW at 15-20 days' interval after sowing *fb.* 2 hoeing. Results shown by Singh *et al*. (2014) [21] also supported maximum rice grain yield could be the reason for higher NUE.

3.4 Availability of major nutrients at harvest

The data of available N, P and K of soil at harvest is presented in Table 1 which indicated that, there was significant difference in the values of available N, P and K of soil as influenced by different fertigation levels and weed management practices after harvest. In case of available N, P and K at harvest, it was observed that maximum value of available N, P and K of soil was observed in treatment of drip fertigation with 125% RDNK in 5 splits i.e.185.38, 21.15 and 374.15 kgha^{-1} respectively and the and the lowest amount of available N, P and K of soil was observed in Drip irrigation with 100% RDF through soil application i.e.175.79, 19.13 and 362.68 kgha^{-1} respectively. Significantly more nitrogen, phosphorus and potassium were remained in soil where higher level of fertilizer dose of 125 per cent RDNK per ha applied through fertigation. While minimum soil available nutrients were observed in soil application of 100 per cent RDF per ha due to leaching and evaporation losses of fertilizer. In case of drip fertigation, significantly higher nutrient content in upper soil layers compared to conventional soil application of fertilizers. While, among the weed management practices, farmer practices i.e. 2 HW at 15-20 days' interval after sowing *fb*. 2 hoeing recorded maximum availability of N, P and K at harvest (195.22, 20.85 and 373.01 kgha^{-1} respectively) followed by Pretilachlor + Pyrazosulfuron ethyl @ 0.615 a.i. kgha^{-1} PE *fb*. Bispyribac sodium @ 0.025 a.i. kgha^{-1} at 25 DAS and lowest availability of nutrients in weedy check. The great improvement in available nutrient status of soil after harvest can be described as the cumulative effect of added nutrient to the soil and indirect addition through leaf drop and root debris backed up by favorable soil microbial activity because of good soil moisture availability through drip irrigation throughout the crop growth which might have converted immobilized organically bound nutrients into inorganic available form. As the weed population was less in herbicidal treatment of Pretilachlor + Pyrazosulfuron ethyl @ 0.615 a.i. kgha^{-1} PE *fb*. Bispyribac sodium @ 0.025 a.i. kgha^{-1} at 25 DAS so the available nutrients status was more in that after harvest. These results are in conformity with the results reported earlier by Sunil *et al*. (2010) [10], Patel *et al*. (2018) [11] and Saravanane (2020) [12].

3.5 Rice grain and straw yield

The results shown in Table 2 indicated that higher fertigation levels significantly increased the grain, straw and biological yield kgha^{-1}) over its lower fertigation levels and conventional soil application with drip. Split application recommended dose of N and K influenced significantly grain and straw yield Significantly highest Grain yield (5103 kgha^{-1}), straw yield (7268 kgha^{-1}) and harvest index (41.25%) were observed at 125% RDNK. The precise application of fertilizers through fertigation resulted in proper feeding of nutrients to the soils at appropriate time with the desired concentration. Fertigation method minimized the nutrient loss that helped in better rice grain straw biological yield and harvest index .

Among the herbicides, the application of Pretilachlor + Pyrazosulfuron ethyl @ 0.615 a.i. kgha^{-1} PE *fb*. Bispyribac sodium @ 0.025 a.i. kgha^{-1} at 25 DAS helped in effective weed management and shifted the crop-weed competition in favour of crop. The better weed management in these treatments resulted in maximum rice grain yield (5231 kgha^{-1}), straw yield (7603 kgha^{-1}) and harvest index of 41.25%. "In weedy check, due to high weed population and high nutrient uptake by the weeds there was decrease in yield of rice crop. Pretilachlor was readily taken up by the hypocotyls, mesocotyls and coleoptiles and to a lesser

extent by roots of germinating weeds; Pyrazosulfuron ethyl inhibited acetolactate synthase in weeds and Bispyribac sodium inhibited the amino acid formation in weeds". Parthasarathi *et al*. (2018) [22], Patil *et al*. (2019) [23]

3.6 Economics of fertigation and weed management practices

Different fertigation levels and weed management practices significantly influenced the economics. The higher level of drip fertigation i.e. drip fertigation at 125% RDNK kg ha^{-1}. registered the highest gross monetary return (₹120353 ha^{-1}), net monetary return (₹72924 ha^{-1}) and B:C ratio (2.54) as indicated in Table 2. (Table 2). Conventional method of fertilizer application (100 % RDF in three splits conventionally) recorded the lowest GMR, NMR and B:C ratio.. The heavy weed infestation in weedy check treatment resulted in lowest GMR due to reduction in grain yield of rice. This might be reason behind the lowest B:C ratio in weedy check. Drip fertigation with 125% RDNK was economically viable than other treatments as there more GMR was obtained. Similar types of result were earlier reported by Nayak *et al*. (2016)[24] and Parthasarathi *etal.* (2018) [21]. "Among the herbicides, application of Pretilachlor+Pyrazosulfuron Ethyl @ 0.615 a.i. kg ha^{-1} PE fb. Bispyribac sodium @ 0.025 a.i. kg ha^{-1} at 25 DAS showed the highest gross monetary return (₹128755/ha), net monetary return (₹81412/ha) and B:C ratio (2.72). Weeds are main enemy of crops as they retarded the growth, development of a crop by competing with the crop for nutrients, water, solar radiation etc". Upasani *et al.* (2012) [25].

4.CONCLUSIONS

The study concluded that higher drip fertigation level of 125 per cent recommended nitrogen and potassium fertilizers and directed application of Pretilachlor + Pyrazosulfuron ethyl @ 0.615 a.i. kg ha^{-1} PE *fb*. Bispyribac sodium @ 0.025 a.i. kg ha^{-1} at 25 DAS was the best treatment combination for enhancing the nutrient uptake, nutrient use efficiency, water use efficiency, availability of major nutrients at harvest and maximizing the rice grain yield and beneficial for increasing the productivity and economic returns of rice under different fertigation levels and weed management practices.

Table 1: Nutrient uptake, water use efficiency, nutrient use efficiency and availability of nutrients as influenced by different treatments

Treatments	Nutrient uptake (kgha^{-1})			WUE (kgha-1 mm)	NUE (kgkg^{-1})	Available nutrient (kgha^{-1})		
	N	P	K			N	P	K
A) Fertigation Levels								
F_1: Drip irrigation with 100% RDF soil application (N in 3 Splits)	96.75	19.25	107.29	3.69	18.63	175.79	19.13	362.68
F_2: Drip fertigation with 75% RDNK in 5 Splits	104.38	21.29	111.59	3.75	23.67	178.24	19.55	366.02
F_3: Drip fertigation with 100% RDNK in 5 Splits	119.22	24.72	127.49	3.86	19.83	181.52	20.60	369.33
F_4: Drip fertigation with 125% RDNK in 5 Splits	133.93	26.99	137.34	4.14	17.91	185.38	21.15	374.15
SE (m)±	5.17	0.99	4.75	--	--	2.67	0.45	3.49
CD (P=0.05)	17.91	3.42	16.44	--	--	8.38	1.54	10.64
B) Weed Management Practices								
W_1:Pendimethalin 1.0 kgha^{-1} PE *fb.*Bispyribac sodium 0.025 kgha^{-1} at 25 DAS	114.72	23.66	122.28	4.06	20.85	180.31	19.23	364.49
W_2:Pretilachlor+Pyrazosulfuron Ethyl 0.615 kgha^{-1} PE *fb.* Bispyribac sodium 0.025 kgha^{-1} at 25 DAS	120.31	24.40	125.91	4.24	21.80	189.84	19.92	369.83
W_3:Pretilachlor 0.75 kg a.i. ha^{-1} PE *fb.* Bispyribac sodium @ 0.025 a.i. kgha^{-1} at 25 DAS	117.52	23.95	124.39	4.13	21.20	183.12	19.43	366.38
W_4:Farmer practices- 2 HW at 15–20 days interval after sowing *fb.* 2 hoeing	123.25	24.68	129.94	4.37	22.45	195.22	20.85	373.01
W_5: Weedy check	92.05	18.62	102.10	2.74	12.41	169.57	18.15	356.78
SE (m)±	5.40	1.27	5.00	--	--	3.51	0.31	3.80
CD at 5%	15.56	3.65	14.40	--	--	10.11	0.90	9.15
Interaction (F×W)								
SE (m)±	10.80	2.53	10.00	--	--	7.01	0.63	1.36
CD (P=0.05)	NS	NS	NS	--	--	NS	NS	NS

Table 2: Grain yield, straw yield (kgha-1)), harvest index (%) and economics of rice as influenced by different fertigation levels and weed management practices

Treatments	Grain yield ($kgha^{-1}$)	Straw yield ($kgha^{-1}$)	Harvest Index (%)	GMR ($₹ha^{-1}$)	NMR ($₹ha^{-1}$)	B:C ratio
A) Fertigation Levels						
F_1: Drip irrigation with 100% RDF soil application (N in 3 Splits)	4471	6593	40.41	108407	62589	2.37
F_2: Drip fertigation with 75% RDNK in 5 Splits	4617	6724	40.71	111168	66639	2.50
F_3: Drip fertigation with 100% RDNK in 5 Splits	4760	6867	40.94	113871	68053	2.49
F_4: Drip fertigation with 125% RDNK in 5 Splits	5103	7268	41.25	120353	72924	2.54
SE (m)±	28.37	45.57	--	536	536	--
CD (P=0.05)	101.00	160.30	--	1853	1853	--
B) Weed Management Practices						
W_1: Pendimethalin 1.0 $kgha^{-1}$ PE *fb.* Bispyribac sodium 0.025 $kgha^{-1}$ at 25 DAS	5004	7294	40.69	124479	75973	2.57
W_2: Pretilachlor+Pyrazosulfuron Ethyl 0.615 $kgha^{-1}$ PE *fb.* Bispyribac sodium 0.025 $kgha^{-1}$ at 25 DAS	5231	7603	40.76	128755	81412	2.72
W_3: Pretilachlor 0.75 $kgha^{-1}$ PE *fb.* Bispyribac sodium 0.025 kg /ha at 25 DAS	5087	7402	40.73	126035	78062	2.63
W_4: Farmer practices- 2 HW at 15–20 days interval after sowing *fb.* 2 hoeing	5389	7656	41.31	131749	80229	2.56
W_5: Weedy check	2978	4350	40.64	56233	13287	1.31
SE (m)±	46.29	72.51	--	874	874	--
CD at 5%	134.00	212.20	--	2519	2519	--
Interaction (F×W)						
SE (m)±	75.43	118.08	--	1748	1748	--
CD (P=0.05)	NS	NS	--	NS	NS	--

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