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Yield Maximization of Rice Varieties under Varying Fertility Levels in Northern Himalayas

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Abstract: A field experiment was conducted during *kharif* 2018 at CSKHPKV, Rice and Wheat Research Centre (RWRC), Malan with the objective of fine-tuning fertility levels for maximizing yield of rice varieties in Northern Himalayas. The experiment consisted of 5 main-plot treatments comprising different fertility levels {50% recommended dose of fertilizer (RDF), 100% RDF (90:40:40), 150% RDF, 50% RDF + Azolla and 100% RDF + Azolla} and 4 varieties as sub-plot treatments {Vivekdhan 65, HPR 2143, HPR 2720 (red rice) and AZ 6508 (hybrid)}. The soil of the experimental site was silty clay loam in texture, acidic in reaction, medium in available nitrogen, phosphorus and potassium. Azolla was applied @ 20-25 g m^{-2} at 10 DAT, which was allowed to multiply *in-situ* for about 2-3 weeks and subsequently trampled twice. The increase in fertility level and Azolla application increased the growth, yield attributes and yield of rice. Application of Azolla increased the rice productivity significantly both at 50 and 100% RDF by 399 and 481 kg ha^{-1}, respectively. Application of 100% RDF + Azolla recorded productivity (5319 kg ha^{-1}) and profitability (INR 79,490 ha^{-1}) which was at par with productivity and profitability achieved with 150% RDF (5192 kg ha^{-1}, INR 75,738 ha^{-1}). Similarly, 50% RDF + Azolla recorded productivity and profitability which was at par with 100% RDF thus revealing a saving of 50% RDF with the use of Azolla. Hybrid 'AZ 6508' recorded maximum grain yield of 6924 kg ha^{-1} followed by Vivekdhan 65 (4822 kg ha^{-1}), red rice 'HPR 2720' (3924 kg ha^{-1}) and HPR 2143 (3740 kg ha^{-1}). The maximum net return (INR 93,924 ha^{-1}) and benefit cost (BC) ratio (2.13) were recorded by the hybrid AZ 6508. Though the productivity of Vivekdhan 65 was more than red rice 'HPR 2720', but due to higher price of red rice it fetched more net return (INR 76,248 ha^{-1}) and B:C ratio (1.94). Interaction effect revealed that the application of 100% RDF + Azolla to the hybrid AZ 6508 produced grain yield of 7430 kg ha^{-1} with net return of INR 101,630 ha^{-1} and BC ratio of 2.23. Thus, farmers of mid-hills of Himachal Pradesh can maximize the rice productivity by growing hybrid AZ 6508 and applying 100% RDF + Azolla @ 20-25 g m^{-2} 10 DAT. Next to hybrid, red rice HPR 2720 is the most profitable choice.

Keywords: Azolla, Rice, Varieties, Fertility levels, Red rice

Rice is one of the most important cereal crop that hold the key towards food security of the world. Rice plays a vital role in ensuring nation's food security and is a means of livelihood for millions of rural households. The population in India is increasing at a rate of 2.2 per cent per annum and is expected to stabilize only around 2050. Vast majority of the farmers in the country derive their livelihood from rice cultivation. Total food grain demand of the country will increase to about 291 million tonnes by 2025 (Kumar and Shivay 2010) and country has to produce about 130 million tonnes of rice by 2025 to feed the growing population (Anonymous 2012). Meeting the targeted demand of food grains is a challenging task for the policy makers, researchers and all other stakeholders. The problem is still confounded as the targeted increase has to be met in the background of declining resource base (land, water, soil productivity, labour, etc.) and increasing environmental concerns. To safeguard and sustain the food security in India, it is therefore, imperative to explore and evaluate such technologies which may increase the productivity of rice under situations of dwindling resource base particularly when there is little scope of horizontal or lateral expansion. Thus, the increase in production has to be vertical and should come from the same cultivated land by way of increased crop productivity. Low yield of rice at farmers' field can be ascribed mainly to the non-availability of thermo-insensitive, early maturing, high yielding varieties, non adoption of new agro technologies. Substantially high rainfall, most of which is concentrated within four monsoon months, results in the loss of the applied nutrients and reduction in the night temperatures also contributes to the low yield of crop.

Therefore, need for approaches for vertical growth in agricultural productivity on sustainable basis, so as to feed this ever increasing population. This would require better planning and resource management besides intensification of cropping. Fertilizers have played a predominant role in increasing the productivity of crops and would continue to do so, provided these are used judiciously as per crop requirement and soil status. However, imbalanced fertilizer use not only results in lower yields but also deteriorates the soil health (This imbalanced nutrient use has resulted in wide gap between crop removal and fertilizer application. Thus,

balanced NPK fertilization has received considerable attention in India (Ghosh et al 2004). It is therefore, necessary to apply fertilizer elements, particularly N, P and K through inorganic sources in optimal quantity to improve and sustain the productivity. In nitrogen, inputs in agricultural systems may be in the form of nitrogen fertilizers, or be derived from atmospheric nitrogen through biological nitrogen fixation (BNF). Therefore, Azolla is a free floating water fern which fixes atmospheric nitrogen in association with the cyanobiont *Anabaena azollae*. The heterocyst of symbiont *Anabaena* is site of nitrogen fixation. Nitrogen fixation associated with high growth rate can enable Azolla to accumulate more than 10 kg N $ha^{-1}day^{-1}$ under optimal growth conditions. In general, a single crop of Azolla is known to provide 20-40 kg ha^{-1} nitrogen and also increases the availability of both macro and micro nutrient but this is insufficient to meet the total nitrogen requirement of the target crop. Therefore, the use of Azolla in combination with chemical nitrogen fertilizers affords a feasible alternative practice (Rao 1999).

In addition to the use of Azolla as a nitrogen source for rice crop, it can be used for reclaiming saline soils, reducing evapotranspiration and to control weed infestations in rice crop and can also be used to purify waste water as it can accumulate P and some heavy metals from water). Azolla is capable of tolerating a wide range of temperature from 5-45°C, so can be used from temperate to tropical environment. Sufficient work has been done on exploitation of Azolla as a bio-fertilizer in rice in other states of country, however limited systematic studies has so far been made in Himachal Pradesh about the usefulness of Azolla in rice production (Thakur 2013).

Besides the inadequate and imbalanced use of fertilizer nutrients as well as non adoption of the recently released rice varieties, is also one of the reasons for low productivity of rice crop. In Himachal Pradesh, many new rice varieties have been released with more productivity, but the farmers are not aware of them. Among them, red rice is acquiring a place in market, because of its high nutritive and medicinal properties. Hybrid rice has become a potential technology for meeting increased global demand of rice as it can outyield all other rice varieties. The hybrid rice is bridging yield gaps in many areas. Doubling the farmer's income by 2022 has been kept as a national goal. To achieve the same, many states in India have documented/implemented multi-pronged strategies; one of them is to increase the crop productivity, as the horizontal expansion is not possible. Rice soils do respond to the organic matter application but on account of the increased demand of FYM for vegetables its availability for rice crop is reducing. Azolla has been found to be promising bio-fertilizer as well as green manure for rice crop.

MATERIAL AND METHODS

The research was carried out during *kharif* 2018 at CSK Himachal Pradesh Krishi Vishvavidyalaya, Rice and Wheat Research Centre, Malan. The experimental field was silty clay loam in texture and acidic in reaction. The soil was rated as high in organic carbon and medium in available nitrogen, phosphorus and potassium. The trial consisted of twenty treatments (5 fertility levels and 4 varieties) which were tested in split plot design with three replications. The experiment consisted of 5 main-plot treatments comprising varying fertility levels {50% recommended dose of fertilizer (RDF), 100% RDF (90:40:40 kg N-P-K ha^{-1}), 150% RDF, 50% RDF + Azolla and 100% RDF + Azolla} and 4 cultivars as sub-plot treatments {Vivekdhan 65, HPR 2143, HPR 2720 (red rice) and AZ 6508 (hybrid)}. Nutrients *viz.,* N, P, and K were applied through urea, di-ammonium phosphate (DAP), and muriate of potash (MOP) in all the plots as per the treatments. Half dose of N and full dose phosphorus and potassium were applied as basal application just before transplanting. The remaining half dose of nitrogen was applied in two split doses at tillering and panicle initiation stages. Plant observations such as plant height, number of tillers, dry matter accumulation, effective panicles, number of grains $panicle^{-1}$, panicle length & weight and 1000-grain weight were recorded at harvest. The crop from each net plot was harvested with the help of sickle after removing the border and sample plant rows. The net plot produce was dried thoroughly for 5 days. When most of the straw in a handful bundle broke up on folding, then total produce was weighed and recorded as biological yield (grain + straw). After the threshed grains were cleaned, the weight of the grains was recorded on electronic balance and converted to kg ha^{-1}. Moisture content in the grains was recorded with moisture meter and the grain yield was adjusted at 14 per cent moisture content. The following formula was used to adjust yield at 14 per cent moisture content

$$\text{Grain yield at 14 per cent moisture} = \frac{100 - \text{moisture (\%) in grain}}{100 - 14} \times \text{Grain yield}$$

The grain yield so recorded from each net plot was subtracted from the biological yield of each net plot to get the straw yield. This straw yield per net plot was then converted to kg ha^{-1}. Treatment-wise cost of cultivation was worked out. The yield of the crop obtained from each plot in the experiment was converted into gross returns in rupees based on prevailing market price of grains and straw. The treatment-wise net returns were obtained by subtracting the cost of cultivation from gross returns. Benefit: cost ratio was calculated by dividing net returns with cost of cultivation as follow:

$$\text{B:C ratio} = \frac{\text{Net returns from treatment (INR } ha^{-1})}{\text{Cost of cultivation of the treatment (INR } ha^{-1})}$$

The statistical analysis of data was done by using OPSTAT online statistical analysis software (Sheoran 2010).

RESULTS AND DISCUSSION

The shoot elongation continued with the advancement in crop age and reached to its maximum at harvest stage (Table 1). Significantly taller plants were recorded with the application of 150% RDF though it was at par with 100% RDF. Application of 50% RDF resulted in significantly shortest plants. Similar results were obtained by Verma et al (2017) where application of 150% RDF recorded significantly tallest plants. Azolla being biological nitrogen fixer, helped in the crop growth. Application of Azolla increased the plant height of rice at both the fertilizer levels of 50 and 100% though the increase was significant only at 50% RDF. Thus, the contributing effect of Azolla was equivalent to 50% RDF. Baktash et al (2021) obtained similar results where application of 50 kg N ha^{-1} + 8 t Azolla recorded highest plant height. Averaged over the fertility levels, main effects of varieties revealed significant variation in plant height at all the dates of observation. Vivekdhan 65 was observed to be significantly taller though it was at par with HPR 2720 at harvest whereas hybrid 'AZ 6508' produced significantly dwarf plants. This was due to genetic makeup of genotypes. Significantly more number of tillers were recorded with the application of 100% RDF + Azolla at all the stages of observation though it was at par with the application of 150% RDF. Application of 50% RDF resulted in significantly least tillers. Application of Azolla benefitted the crop and number of tillers per unit area increased significantly at both 50 & 100% RDF. The improvement in the formation of tillers with increase in fertility level and Azolla application might be due to increase in nutrient availability which enhanced tillering. Razavipour et al (2018) have also reported similar findings. The number of tillers per square meter were significantly more in Vivekdhan 65 being at par with the hybrid AZ 6508, revealing that tiller mortality was less in hybrid. The other treatments with respect to tiller count were in order of HPR 2143>HPR 2720. Application of 100% RDF + Azolla recorded significantly higher dry matter accumulation compared to 150% RDF. This may be attributed to the fact that increase in fertility level and Azolla application might have continuously supplied the nitrogen and helped in increasing the dry matter accumulation because nitrogen is directly involved in vegetative growth. Application of Azolla saved the 50% RDF. These findings are in agreement with Razavipour et al (2018). Taller variety Vivekdhan 65 recorded significantly highest dry matter. The other varieties with respect to dry matter were in order of AZ 6508>HPR 2143>HPR 2720. The increase in fertility level increased the number of effective panicles, grains $panicle^{-1}$, panicle weight and 1000-grain weight consistently and significantly. Significant increase in number of effective panicles, grains $panicle^{-1}$, panicle weight and 1000-grain weight were observed with Azolla application at both 50 and 100% RDF. Significantly highest number of effective panicles were recorded with the application of 100% RDF + Azolla (F_5) which was statistically same as with 150% RDF (F_3). Baktash et al (2021) also observed that application

Table 1. Effect of varying fertility level and varieties on growth, yield attributes and of rice at harvest

Treatment	Plant height (cm)	Dry matter accumulation (kg m^{-2})	Number of tillers m^{-2}	Number of effective panicles m^{-2}	Number of grains $panicle^{-1}$	Panicle length (cm)	Panicle weight (g)	1000 grain weight (g)	Grain yield (kg ha^{-1})	Straw yield (kg ha^{-1})
Fertilizer level										
F_1: 50% RDF	106.7	1016.2	9764	163.5	129	24.02	2.82	22.5	4257	5508
F_2: 100% RDF	112.0	1123.7	10899	185.4	146	25.25	3.06	22.9	4838	6061
F_3: 150% RDF	115.1	1261.3	11624	198.2	156	25.05	3.20	23.6	5192	6432
F_4: 50% RDF + Azolla	111.9	1103.6	10542	174.4	139	24.56	2.96	22.9	4656	5886
F_5: 100% RDF + Azolla	115.1	1318.9	11798	201.2	165	25.33	3.33	23.9	5319	6479
CD (P=0.05)	3.7	54.8	769	6.2	11.7	NS	0.32	0.4	350	423
Varieties										
V_1: Vivekdhan 65	124.7	1340.2	12033	196.9	123	24.05	2.72	24.9	4822	7211
V_2: HPR 2143	105.6	1123.5	9462	179.0	131	25.17	2.61	24.5	3740	5723
V_3: HPR 2720	122.4	1050.0	9709	169.3	150	25.54	2.69	16.5	3924	5785
V_4: AZ 6508	95.9	1145.4	12498	192.8	184	24.59	4.29	26.8	6924	5574
CD (P=0.05)	2.9	49.2	278	4.4	6.1	0.67	0.23	0.2	126	167

of 100 kg N ha^{-1} + 4 t Azolla increased the effective panicle m^{-2} of rice. Srivastava et al (2014) and Gohain (2014) also found similar trend. Vivekdhan 65 produced significantly higher number of effective panicles m^{-2} being statistically at par with AZ 6508 while HPR 2720 produced significantly lowest panicles. Number of grains $panicle^{-1}$ were significantly highest in AZ 6508 followed by HPR 2720 and HPR 2143 whereas Vivekdhan 65 recorded significantly lowest grains $panicle^{-1}$. HPR 2720 recorded significantly higher length of panicle than Vivekdhan 65 and AZ 6508 but was at par with the variety HPR 2143. Significantly highest panicle weight was recorded by hybrid AZ 6508. Significantly lower panicle weight was obtained in the variety HPR 2143 being at par with HPR 2720 and Vivekdhan 65. The hybrid AZ 6508 recorded significantly more 1000-grain weight (26.8 g) followed by Vivekdhan 65 (24.9 g), HPR 2143 (24.5 g) and HPR 2720 (16.5 g). These are the varietal characters which are varied from variety to variety. Similar results have also been reported by Razavipour et al (2018). The grain yield of rice increased with increasing fertility level with significantly higher yield recorded with the application of 150% RDF while significantly lower yield recorded with application of 50% RDF. The lowest yield obtained with the application of lowest dose was due to the inability of the soil to provide adequate quantity of nutrients to the rice crop while adequate supply of nutrients in treatments where higher dose of fertilizers were applied which led to higher yields. Similar results have been reported by Patel and Mishra (2014).

Application of Azolla also had a positive effect on grain yield of rice. The grain yield obtained with the application of 100% RDF was at par with the yield obtained with the application of 50% RDF along with Azolla inoculation. Similarly yield recorded with the application of 150% of RDF was at par with yield recorded with 100% RDF along with Azolla inoculation. Azolla application increased the grain yield over both the fertility levels of 50 and 100% RDF and the magnitude of increase was 8.57 (399 kg ha^{-1}) and 9.04 per cent (481 kg ha^{-1}), respectively. The results are indicative of the possibility of economizing 50% RDF with the use of Azolla in transplanting rice. The increase in yield as a result of Azolla use was due to the nitrogen fixed by the bio-fertilizer which was made available to rice crop during the late vegetative or reproductive phase. The organic matter added to the soil as a result of Azolla incorporation improved the physical condition of the soil which provided better environment to the crop for achieving higher yield. Yao et al (2017) substituted 25% nitrogen through Azolla bio-fertilizer. Baktash et al (2021) observed highest grain yield with the application of fertilizer with Azolla. The results are in conformity with earlier researchers (Kumar et al 2017, Razavipour et al 2018 , Grace et al 2018). Significant variation was also observed amongst varieties in term of grain yield with hybrid 'AZ 6508' producing significantly higher grain yield followed by Vivekdhan 65, HPR 2720 and HPR 2143, in that order, each variety differing significantly from one another. The highest yield was in AZ 6508 was due to significantly higher number of effective panicles per unit area, number of grains per panicle and 1000-grain weight recorded in this variety. Srivastava et al. (2014) reported similar results of hybrid rice. The lowest grain yield was in HPR 2143. Patel and Mishra (2014) also mentioned similar trend. Straw yield was significantly more with the application of 100% RDF + Azolla (6479 kg ha^{-1}) being at par with the treatment 150% RDF (6432 ha^{-1}) and 100% RDF (6061 kg ha^{-1}). This may be attributed to the fact that increase in fertility level and Azolla application might have continuously supplied the nitrogen and helped in boosting the vegetative growth. Srivastava et al (2014) observed significantly higher grain and straw yield with increase in fertility level. Baktash et al (2021) found that application of chemical fertilizers with Azolla gave significantly higher grain and straw yield. The taller plants and more tiller count resulted in significantly higher straw yield in Vivekdhan 65 (7211 kg ha^{-1}). The significantly lower straw yield was obtained from dwarf 'AZ 6508' (5574 kg ha^{-1}) being at par with HPR 2143 (5723 kg ha^{-1}).

Interaction effects of varying fertility level and varieties on grain yield: At all the levels of fertility, hybrid 'AZ 6508' produced significantly highest grain yield followed by Vivekdhan 65 (Table 2)**.** The yield from other two varieties HPR 2143 and HPR 2720 was at par at all the fertility levels

Table 2. Interaction effect of varying fertility level and varieties on grain yield of rice

Treatment	F_1: 50% RDF	F_2: 100% RDF	F_3: 150% RDF	F_4: 50% RDF + Azolla	F_5: 100% RDF + Azolla
Vivekdhan 65	4283	4815	5257	4610	5143
HPR 2143	3273	3680	4020	3693	4032
HPR 2720	3293	3873	4247	3537	4671
AZ 6508	6177	6983	7243	6785	7430
CD (P=0.05)					
For comparison of two varieties at same fertility level					281
For comparison of fertility levels at same or different varieties					464

except at treatment in which 100% RDF was applied along with Azolla. Varieties also behaved differentially in their response to added fertilizers with the yield increasing significantly with increasing fertilizer application from 50 to 100% RDF in all the varieties except HPR 2143 where the increase was not significant. Further increasing the fertilizer application from 100 to 150% RDF also increased the yield in all the varieties though the increase was not significant. Additional inoculation of the rice crop with Azolla also increased the yield at both the fertility levels of 50 and 100% RDF though the increase was significant only for AZ 6508 when the crop was fertilized with 50% RDF along with Azolla application. Azolla application saved the 50 per cent of fertilizer application. AZ 6508 recorded productivity level of 7430 kg ha^{-1} with 100% RDF + Azolla.

Economics of rice: The increase in fertilizer level from 50 to 100% RDF, significantly increased the gross returns and net return (Fig. 1). The gross returns and net return was significantly higher with the application of 100% RDF + Azolla being at par with 150% RDF. AZ 6508 recorded significantly higher gross returns and net return (INR 137,886 ha^{-1} & INR 93,924 ha^{-1}, respectively) followed by HPR 2720 (INR 115,460 ha^{-1} & INR 76,248 ha^{-1}). Significantly higher value of BC ratio was observed with the application of 100% RDF + Azolla being at par with the 150% RDF. Hybrid AZ 6508 (2.13) recorded significantly higher BC ratio followed by HPR 2720 (1.94). The interaction showed that significantly higher B:C ratio was recorded from AZ 6508 at all the fertility levels being at par with HPR 2720 when fertilized with 150% RDF except at 100% RDF + Azolla at which significantly higher BC ratio was recorded from variety HPR 2720 being at par AZ 6508.

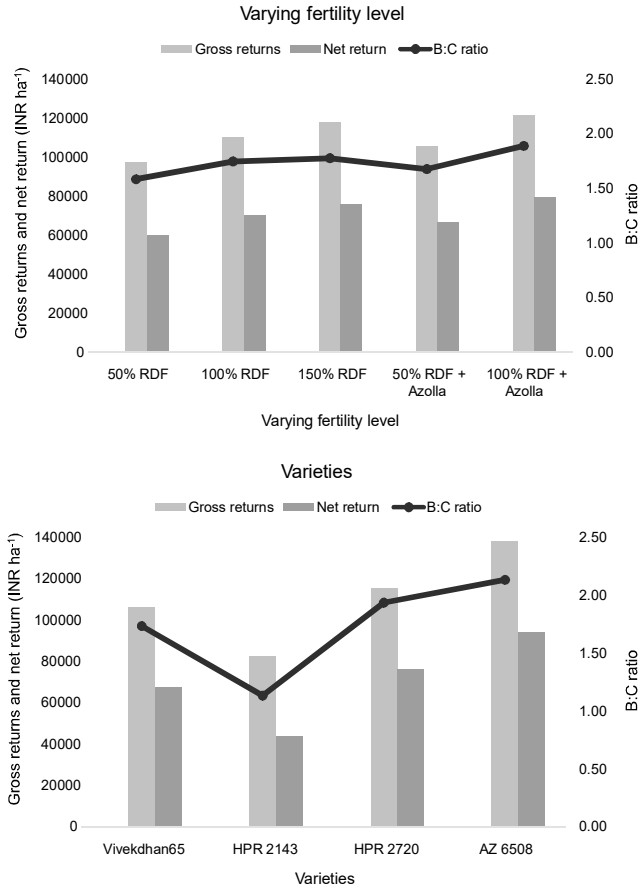

Fig. 1. Effect of varying fertility level and varieties on economics of rice

CONCLUSION

Hybrid 'AZ 6508' with the application of 100% RDF (90:40:40) + Azolla @ 20-25 g m^{-2} 10 DAT achieved maximum productivity and profitability of rice in North-Western Himalayas. The next best option is red rice variety 'HPR 2720' with the same fertility management. For resource poor farmers, Hybrid 'AZ 6508' can also be a good option even at lower fertility level (50% RDF).

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