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Research Article

Assessing Growth, Productivity and Profitability of Drought Tolerant Rice Using Nutrient Expert - Rice and Other Precision Fertilizer Management Practices in Lamjung, Nepal

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Abstract

The overall production and productivity of rice (*Oryza sativa* L.) in Nepal is far behind the developed countries and its production has remained constant since several years and the inappropriate use of fertilizers ranked the major challenge in Nepal. A field experiment was conducted in the Agronomy Farm of Lamjung campus to assess the productivity and profitability of drought tolerant rice cultivar (Sukha-3) using Nutrient Expert®-Rice model and other precise fertilizer management practices. The study was conducted from June to November, 2017 with six treatments and four replications in Randomized Complete Block Design (RCBD). The treatments adopted were: farmer's fertilizer practices (FFP); Nutrient Expert-Rice model (NE), Leaf Color Chart (LCC, (N) and FFP (P&K); NE (N) and FFP (P&K); and LCC (N) and FFP (P&K). The statistical result revealed the significant differences between the treatments in terms of grain yield, yield attributing characters and economic parameters. The highest grain yield was found in NE recommended fertilizer dose (5.14 t/ha) followed by LCC(N) and NE(P and K) (4.47t/ha). The significantly higher net revenue was recorded in treatment NE (NRs. 64,249/ha) and the lowest net revenue was found in treatment NE (N) and FFP (P&K) (NRs 7,305/ha). While comparing Nutrient Expert (NE) estimated attainable rice yield with the actual rice yield in the farmer field trial, NE- based fertilizer recommendations proved to be successful in reaching the yield targets estimated by NE-Rice software. Hence, the experiment concluded that Nutrient Expert®-Rice model could be used as a practical tool for decision support system to make more authentic fertilizer recommendation.

Keywords: Farmer's Fertilizer Practice; Government Recommendation; Leaf Color Chart; Nutrient Expert- Rice; Productivity; Profitability

Introduction

Rice (*Oryza sativa*) a monocot, is an annual plant, although in tropical areas it can survive as a perennial and can produce a ratoon crop for up to 30 years. Rice is a staple food crops for 60% of the world's population, supporting the lives of billions of people all over the world. Rice cultivation is suited to those areas and regions with low labor cost and high rainfall since it is labor-intensive and requires ample water. However, rice can be grown practically anywhere, even on a steep hill or mountain area with the use of water-controlling terrace systems. Rice is the source of 27% of dietary energy and 20% of dietary protein in the developing world (Redona, 2004).

The area, production and productivity of paddy in Nepal is 1.55 million ha, 5.23 million ton and 3.369 ton / ha respectively (MoAD, 2016/17). 20% of agricultural gross domestic product is contributed by rice alone. The total cultivated area under rice in the Lamjung district is 16.45 thousand ha, while the average yield is 2.86 t ha-1 (MoAD, 2012/13). Poor irrigation facility has always been a problem to the farmers of lamjung district, thus hindering the crop growth and production. In the current fiscal year, gross food production of Nepal (rice, wheat, maize, millet, barley and buckwheat) is estimated to reach 8.692 million metric tons with a decline of 6 percent from the previous fiscal year. Likewise, paddy rice production is likely to fall by 10.2 percent to 4.299 million metric tons in the same period (GON of ministry of finance, 2016). The major reasons behind this is nutrient imbalances, inefficient fertilizer use and large losses to the environment. The knowledge of how establish a proper fertilizer recommendation for small land holding farmers has remained as a challenge. Rice productivity is also threatened by abiotic stresses such as drought. About 33% of the land where rice is cultivated is directly affected by drought which is about 0.52 million hectare land (NARC, 2014). Development and use of drought tolerant rice variety is a boon for the farmers struggling to cope with little water [1].

Existing fertilizer recommendations for rice often consist of fixed rates of N, P, and K for vast areas. The growth and needs of a crop for supplemental nutrients are actually not constant and can instead vary among fields, seasons, and years as a result of differences in crop-growing conditions, crop and soil management, and climate. Hence there is haphazard use of fertilizers; underutilization in one and over utilization in the other. Hence the concept of site specific nutrient management was introduced with the aim of supplying fertilizers based on specific sites and field conditions and the growing environment. SSNM is a component of precision agriculture which combines the plant nutrient requirements at each growth stage and soil's ability to supply those nutrients. Nutrient expert model is based on the principle of SSNM. It is computer based decision support tool that account for indigenous nutrient sources, crops including crop residues and manures; and apply fertilizer at optimal rates and at critical growth stages to meet the deficit between the nutrient needs of a high-yielding crop and the indigenous nutrient supply.

LCC is a simple, inexpensive low tech tool of SSNM that is well suited as an indicator of leaf N status for small scale farmers in Asia. It enables the application of N as per crop demand which enhances the N use efficiency in crops. The approach is known as real- time N management. This approach avoids the excessive N application by matching time and amount of fertilizers as per the plant need.

Materials and Methods

The research was carried out in agronomy farm of lamjung campus, Sundarbazar municipality in western mid hills of Nepal during rainy season 2017. The preliminary questionnaire was prepared based on nutrient expert model software. The detail information was collected by interviewing the farm men. The obtained data were entered into NE rice software and the different doses of nitrogen through urea, phosphorous from DAP and potassium from potash was recommended for the same field. The experiment was laid out in randomized complete block design with six treatments and four replications with the gross plot size was 6m2 and net plot size of 1m^2. The treatments adopted were Farmer's fertilizer practice (FFP), government recommendations (GR), Nutrient expert (NE), Leaf color chart (LCC) (N), nutrient expert (NE) (P,K), Nutrient expert (NE) (N), farmer's fertilizer practice (FFP) (P,K), Leaf color chart (LCC) (N), farmer's fertilizer practice (FFP) (P,K). sukhadhaan-3 was sown in 2nd week of June and harvesting was done in 1st week of November. Pre- harvest observation (plant height, effective and non-effective tillers per hill, panicle length), post- harvest observations (grain yield (t/ha), straw yield (t/ha), no of grains per panicle, filled and unfilled grains per panicle, fertility percentage (%), harvest index (HI)) and economic analysis (cost of cultivation, gross revenue, net revenue and benefit-cost ratio) were taken. Data entry and analysis was done using MS excel SPSS 16.0 and R 3.1.1 were used for statistical analysis. ANOVA was performed at 0.05% level of significance.

Results and Discussion

Treatments	Plant height (cm)	Panicle length (cm)	Effective tillers/hill	Tiller panicle conversion index (TPCI)	Leaf area Index (LAI)	Filled grains/ panicle	Fertility (%)	Test weight (g)
FFP	103.44^b	18.31^d	490^c	0.7862	3.441^{cd}	144.81^C	0.923^b	19.36^b
GR	107.23^{ab}	21.38^{abc}	5.12^{bc}	0.7803	3.088^d	148.12^{bc}	0.933^a	22.89^{ab}
NE	111.19^a	24.07^a	5.80^a	0.819	7.41^a	154.00^a	0.936^a	26.13^a
LCC (N), NE (PK)	107.15^{ab}	22.06^{ab}	5.55^{ab}	0.759	6.47^{ab}	151.40^{ab}	0.933^a	20.58^b
NE (N) FFP (PK)	103.71^b	20.11^{bcd}	5.12^{bc}	0.719	227^d	140.40^d	0.923^b	20.58^b
LCC (N) FFP (PK)	101.54^b	19.14^{cd}	5.12^{bc}	0.830	5.1 8^{bc}	139.05^d	0.925^b	18.70^b
SEM (±)	16	3.044	0.11	0.00811	1.433	5.96	6.37	8.13
LSD(0.05)	6.02	2.62	0.51	12.57	1.804	3.67	0.00380	4.29
CV (%)	3.78	836	6.49	0.135	25.75	1.668	0.271	13.50
Significance	*	**	*	NS	***	***	***	*

Table 1: Different growth and yield attributes of rice as affected by different nutrient management practices.

Highly significant = '***', **, significant= *, non- significant= NS

Plant height

Plant height was significantly affected by different nutrient management practices. The plant height was found more in NE (111.19 cm) and the lowest was found in NE (N) FFP (PK) (103.71 cm) LCC (N) FFP (PK) (101.54 cm) and FFP (103.44 cm). LCC (N) NE (PK) (107.15 cm) and GR (107.23 cm) was found to be statistically at par with NE. The result is similar to the findings of Salam., *et al.* [2], Haq., *et al.* [3] and Awan., *et al.* 1984 which reported that the balanced and high dose of NPK at specific site contribute to the plant height.

Panicle length

Highly significant difference was found in case of panicle length. The longest panicle length was found in NE (24.07 cm) and the lowest one was found in FFP (18.31 cm). LCC (N) NE (PK) (22.06 cm) and GR (21.38 cm) was found statistically at par with NE.

Effective tillers

Significant difference was obtained in effective tillers per hill. The highest no of effective tillers was found in NE (5.80) and the lowest was found in FFP (4.90). LCC (N) NE (PK) (5.55) has similar no effective tillers with NE and are statistically at par with each other. The role of nitrogen available to the plant from soil in cell division causing increase in no of effective tillers is reported by Mirzae., *et al* 2010. NE MT Haq., *et al.* [3] and Uddin., *et al.* 1998 reported that the balanced and optimum fertilizer application increases the number of effective tillers.

Leaf area index

Highly significant result was observed in leaf area index (LAI). LAI was found the highest in NE (7.41) and the lowest was found in NE (N) FFP (PK) (2.27). LCC (N) NE (PK) (6.47) is statistically at par with NE.

Filled grains per panicle

Highly significant result was obtained in filled grains per panicle. The highest filled grains were found in NE (154.00) and the lowest was found in LCC (N) FFP (PK) (139.05). LCC (N) NE (PK) (151.40) is found to be statistically at par with NE. Shokri., *et al.* (2009) reported that the availability of nitrogen in soil is essential for greater no of filled grains per panicle

Test weight

Significant difference was found between the treatments in case of test weight. The highest test weight was found in NE (26.13g) and all other treatments have same test weight except GR (22.89g) which is statistically at par with NE. Manzoor Z, Awan TH., *et al.* reported that test weight was found higher (27.96g) if 175kg of nitrogen applied due to increase in chlorophyll content in leaves which lead to higher photosynthesis rate and ultimately plenty of photosynthesis available during grain development.

Fertility percentage

Statistically highly significant result was obtained in case of fertility percentage. Treatment NE (0.936%), LCC (N) NE (PK) (0.933%) and GR (0.933%) has the highest fertility percentage.

Treatment	Grain yield (t/ha)	Straw yield (t/ha)	Biomass yield (t/ha)	Harvest index (HI)
FFP	4.02^{bc}	5.53^{abc}	9.55^{bc}	0.420
GR	4.24^{bc}	6.08^{a}	10.32^{b}	0.409
NE	5.14^{a}	6.52^{a}	11.66^{a}	0.441
LCC (N) NE (PK)	4.47^{b}	5.76^{ab}	10.24^{b}	0.438
NE (N) FFP (PK)	3.81^{c}	4.69^{c}	8.50^{c}	0.448
LCC (N) FFP(PK)	3.95^{bc}	5.00^{bc}	8.95^{c}	0.443
SEM	0.13	0.38	0.482	0.00136
LSD	0.55	0.93	1.046	0.055
CV	8.58	11.05	7.030	8.511
Significance	**	**	***	NS

Table 2: Yield character of rice under different nutrient management practices.

Highly significant= ***, ** significant= *, non-significant= NS

Grain yield

Result revealed the highly significant differences in grain yield among the different treatments. The highest yield was found in NE (5.14 t/ha) followed by LCC (N) NE (PK) (4.47 t/ha). The lowest grain yield was found in LCC (N) FFP (PK) (3.95 t/ha). The yield obtained in NE is approximately 1.15t more than FFP. The increased percentage in yield of NE over FFP is 27.86%. Dobermann., *et al.* [4-6] reported that in 56 on- farm experiment conducted with transplanted rice, site specific management of macronutrients increased yields of rice by 17% as compared to farmer's fertilizer practice(FFP)and overall average yield by 7%.

Witt., *et al.* [7,8] reported the SSNM and FFP differed in the amount of N, P, K applied across different countries. N rate was found higher (27.1 kg/ha) in SSNM compared to FFP in Philippines while on average across the three countries, 16 kg/ha less N was applied in SSNM plots than in FFP. SSNM led to the production higher grain yield due to increased N use efficiency. An average increase of 53% grain yield was found compared to the FFP. Haque MA., *et al.* [9] also reported that N use efficiency was much higher in LCC based N application. Approximately 19 - 37 kg N/ha was found saved in LCC. Partial factor productivity of N is found to be increased by LCC based fertilizer which indicates higher NUE. In an experiment it was found over nine genotypes of N in LCC was 102 and in farmer practice was only 62.

Other studies including NE model maize and wheat also showed the significant yield advantage from tool based fertilizer recommendation as compared to existing practices [10].

Straw yield

Straw yield differs significantly with different nutrient management practices. Straw yield was found highest in NE (6.52 t/ha) and the lowest was found to be in NE (N) FFP (PK) (4.69 t/ha). LCC (N) NE (PK) (5.76 t/ha) was found statistically at par with NE. Straw yield in NE treatment is found 1.19 more than that of the FFP. The increased straw yield of NE over FFP is 21.51%.

Straw yield is the function of vegetative growth. Balanced and optimum use of fertilizer increases the plant height, green leaves per hill and dry matter production which finally resulted in higher straw yield.

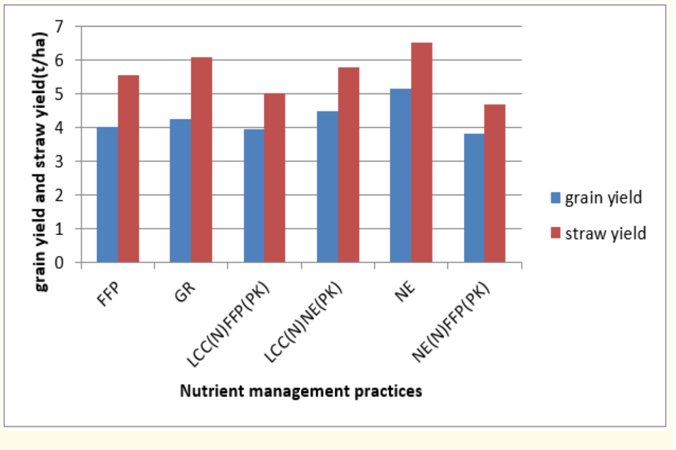

Figure 1: Comparison of grain yield and straw yield in different treatments.

Biomass yield

Biomass yield was found significantly affected by the different nutrient management practices. Higher biomass yield was found in NE (11.66 t/ha) followed by GR (10.32 t/ha) and LCC (N) NE (PK) (10.24). The lowest grain yield was found in NE (N) FFP (PK) (8.50 t/ha).

Figure 2: Correlation between grain yield and effective tillers per hill.

Figure 3: Correlation between grain yield and filled grain per panicle.

Cost of cultivation

Significant differences were found in cost of cultivation between the treatments. Higher cost of cultivation was found in GR (161514.2 NRs/ha) followed by NE (160186.5 NRs/ha). The lowest cost of cultivation was found in LCC (N) FFP (PK) (156101.7 NRs/ha). The reason for high cost of cultivation is the application of large proportion of nutrient.

Figure 4: Correlation between grain yield and leaf area index (LAI).

Treatment	Cost of cultivation (CC)	Gross revenue (GR)	Net revenue (NR)	Benefit cost ratio (b/c)
FFP	158700^{bc}	178145.5^{bcd}	19445.4^{bc}	1.12^{bc}
GR	161514.2^{a}	189224.7^{bc}	27710.54^{bc}	1.17^{bc}
NE	160186.5^{ab}	224436.0^{a}	64249.51^{a}	1.40^{a}
LCC (N) NE (PK)	157539.7^{cd}	195782.2^{b}	38242.54^{b}	1.24^{b}
NE (N) FFP (PK)	158058.1^{bcd}	165363.8^{d}	7305.72^{c}	1.045^{c}
LCC (N) FFP (PK)	156101.7^{d}	172294.9^{cd}	16193.21^{c}	1.103^{c}
SEM	2241467	1870000	17860000	0.00703
LSD	2256.45	20259.9	20141.92	0.126
CV%	0.9434	7.16	46.31	46.28
Sig.	**	***	***	***

Table 3: Economic analysis of rice production.

Highly significant= ***, ** significant= *, non- significant= NS

Note: cost of cultivation, gross revenue and net revenue are in Nepalese rupees per hectare.

Gross revenue

Highly significant result was obtained in case of gross revenue between different treatments. Higher gross revenue was found in NE (224436.0 NRs/ha) which is followed by LCC (N) NE (PK) (195782.2 NRs/ha). Higher gross revenue in NE was due to high grain and straw yield.

Net revenue

Highly significant result was obtained in net revenue between the treatments. The net revenue was found higher in NE (64249.51 NRs/ha) followed by LCC (N) NE (PK) (38242.54 NRs/ha). The lowest net revenue was found in NE (N) FFP) (PK) (7305.72 NRs/ha).

Benefit- cost ratio (B/C ratio)

Benefit cost ratio differs significantly among the treatments. High benefit cost ratio was found in NE (1.40) followed by LCC (N) NE (PK) (1.24). Benefit cost ratio was found lowest in LCC (N) FFP (PK) (1.103). This is because of high gross revenue in NE above cost of seed and fertilizer than all other treatments [11-19].

Conclusion

The above discussed growth, productivity and profitability of rice proved that the difference between the treatments was found highly significant in terms of plant height (cm), panicle length (cm), effective tillers per hill, tiller panicle conversion index (TPCI), leaf area index (LAI) filled grains per panicle, fertility %, test weight (g), grain yield (t ha^{-1}), straw yield (t ha^{-1}), biomass yield (t ha^{-1}). However, the highest grain yield was found in NE recommended fertilizer dose (5.14 t/ha) followed by LCC (N) and NE (P and K) (4.47t /ha), GR (4.24 t/ha), FFP (4.02 t/ha), LCC (N) FFP (PK) (3.95 t/ha) and NE (N) FFP (PK) (3.81 t/ha).

In addition, cost of cultivation (NRs per ha), gross return (NRs per ha), net return (NRs per ha) and benefit cost ratio differed significantly among the treatments. The highest net revenue was recorded in treatment NE (NRs. 64,249/ha) and the lowest net revenue was found in treatment NE (N) and FFP (P&K) (NRs 7,305/ha).

Thus, higher yield and maximum profit can be generated through a nutrient recommendation from Nutrient Expert® rice model. This shows that NE based fertilizer recommendation was found to be superior in terms of both yield and economics signifying its validity. And LCC (N), NE (PK) was found better after NE in terms of both yield and economics.

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