Int.J.Curr.Microbiol.App.Sci (2020) *9*(5): 2250-2259

International Journal of Current Microbiology and Applied Sciences
***ISSN: 2319-7706* Volume 9 Number 5 (2020)**
Journal homepage: http://www.ijcmas.com

Original Research Article https://doi.org/10.20546/ijcmas.2020.905.256

On-farm Assessment of Balanced Crop Nutrition on Productivity and Nutrient Use Efficiency in Rice (*Oryza sativa* L.) – Horse Gram [*Macrotyloma uniflorum* (Lam.) Verdc] Cropping System in South Konkan Coastal Zone of Maharashtra

A. V. Dahiphale[1]*, S. B. Bhagat[1], N. V. Mhaskar[2], D. G. Jondhale[2], T. J. Bedse[2] and P. B. Vanve[2]

[1]AICRP-IFS, Regional Agricultural Research Station, Karjat, Dist. – Raigad, Maharashtra, India
[2]Regional Agricultural Research Station, Karjat, Dist. - Raigad Maharashtra Dr Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli, India

**Corresponding author*

Keywords

On farm research, Rice-horse gram system, Agronomic efficiency, Partial factor productivity, Marginal returns

Article Info

Accepted:
15 April 2020
Available Online:
10 May 2020

A B S T R A C T

Enhancing the nutrient use efficiency (NUE) in rice based food production systems of south konkan coastal zone of Maharashtra has always been an area of great focus as costs of production is increasing which ultimately results in reducing the productivity of the area and reduce the response of crop to recommended nutrient management. An experiment 'On farm assessment of plant nutrients in rice –horse gram cropping systems' were conducted during the year 2017–18 through farmer participatory approach in rice based food production systems of south konkan coastal zone of Ratnagiri district of Maharashtra. A total of 24 farmers in six different villages (four per village) of two blocks (Lanja and Rajapur) in area were selected. An experiment in farmers filed on rice–horse gram systems were conducted with various 7 treatments, *viz.*, T_1-Control, T_2-Recommended N alone, T_3-Recommended N and P, T_4-Recommended N and K, T_5-Recommended N, P and K, T_6-Recommended NPK with $ZnSO_4$ and T_7-Farmers' practice. Results reveled that across the six various villages of the zones and cropping systems, farmers applied lower level of N, P_2O_5, K_2O and no amount of micronutrients as per recommendation. Application of recommended dose of NPK and micronutrient in every village in rice-horse gram system recorded higher system rice equivalent yield (REY kg/ha) over the farmer package, appropriate recommended NPK and micronutrients significantly boosted the yield. Improvement in agronomic efficiency (AE) of nitrogen, partial factor productivity of nitrogen and relative response was also reported at upper level with the combination of NPK+ Zn compared to N, NP and NK alone. Whereas in case of economics incremental benefits were recorded in net returns (rs/ha) and in benefit cost ratio (B: C ratio) at all the location.

Introduction

Pulses grown on 22-24 M ha area in country and rice was cultivated on 44.14 m ha area with production of 111.87 MT. India has achieved noteworthy increase in food production in the post-green revolution phase, from 90 million tonnes in 1969–70 to 291.95 million tonnes in 2019-20. India is the largest producer (25% of global production), consumer (27% of world consumption) and importer (14%) of pulses in the world. In sequential cropping system involving pulses, the preceding pulse may contribute 18-70 kg N/ha to the soil which is made available to the next crop in sequence (Ali and Mishra 2000). Occurrence of multi nutrient deficiency due to imbalanced use of nutrients and declining soil organic matter are the factors affecting the productivity of rice –horse gram cropping sequence at the farmers' field. With a consumption of 16.95 Tg N, 6.850 Tg P2O5 and 2.77 Tg K2O in 2017-18. However, nutrient use efficiency (NUE) in India has always been major issue. In the last 35 years, fertilizer response in irrigated areas of the country has declined almost three times from 13.4 kg grain/kg NPK in 1970 to 3.7 kg grain/kg NPK in 2005. Nitrogen application has made substantial contribution to the tripling of global food production over the last five decades. However, its use efficiency in agriculture is in general low and ranges between 20% and 50%. Imbalanced application of essential nutrients (secondary and micro) is one of the reasons for low nitrogen use efficiency. Improved nitrogen management will certainly save the nitrogen loss with increasing in NUE. Time and rate of application is a key for higher profitability and productivity. Proper scheduling of nitrogen is necessary for improving its use efficiency depending on climatic situation, rainfall pattern and soil type (Dahiphale *et al.*, 2018). In Maharashtra, rice is cultivated on 15.56 lakh ha area. In Konkan regions rice was grown on 3.69 lakh ha with the highest productivity of rough rice was in Konkan region 4.25 t ha-1 (Anon. 2017). In konkan region traditional rice based cropping systems followed under residual moisture situations. As horse gram crop are very well known for its ability to improving soil fertility restoration value, deep rooting, nitrogen fixation, leaf shedding ability are some of the focusing issue of the horse gram. Inclusion of horse gram crop in intensive rice based system is step towards integrated plant nutrient supply system. Therefore, horse gram has become viable alternative to improve the soil health and improve nutrient management efficiency in south konkan region. Considering this fact, a farmer's participatory research was carried out at farmers' field to quantify response of the nutrients in rice – horse gram cropping system in south konkan region.

Materials and Methods

An experiment was conducted in (6) six different villages of two blocks of Lanja and rajapur in Ratnagiri district, situated in south costal konkan Zone of Maharashtra on "On farm assessment of plant nutrients in rice – horse gram cropping systems under south konkan coastal zone of Maharashtra" to assess the response of rice –horse gram systm to different nutrients combinations during the year 2017-18 at farmers' field. After appropriate bench mark survey of twenty-four (24) farmers were selected from 6 different villages, spread in 2 blocks (Lanja and Rajapur) of Ratnagiri district situated in south konkan coastal zone of Maharashtra adopted by On-Farm Research Centre, All India Coordinated Research Project on Integrated Farming Systems, Dr Balasaheb Sawant Konkan Krishi vidyapeeth, Dapoli. The seven treatments, *viz.*, T_1-Control, T_2-Recommended N alone, T_3- commended N and P, T_4-Recommended N and K, T_5-

Recommended N, P and K, T_6- Recommended NPK with $ZnSO_4$ and T_7- Farmers' practice were taken for study on each selected farmers field. The soils of the experimental sites was red laterite with pH 5.24, Electrical conductivity 0.08 (dS m^{-1}), Organic Carbon 12.5 (g kg^{-1}) and available N, P and K was 290.25, 14.05 and 96.8.16 kg ha^{-1} respectively. In the treatment T_6 (NPK+$ZnSO_4$), $ZnSO_4$ was only applied to Kharif rice crop not to the Rabi horse gram. Particulars of farmers' fields with on-farm experiments at six village's locations are given in table 1. Applied recommended levels of N, P, K, and Zn, Kg ha^{-1} ,genotypes grown, duration of genotype and date of transplanting/sowing of rice-horse gram cropping system used are presented in table 2. In rice –horse gram cropping system the crops production was done by following all standers package of practices. The system productivity was calculated by converting the yield of rice in to rice equivalent yield (REY) of horse gram by. Rice equivalent yield of horse gram crops was calculated by multiplying the yield of the respective crops with their price and then dividing by the price of rice. REY of horse gram = [(horse gram yield x price of horse gram) / (price of rice)]. In case of nutrient use efficiencies (NUE) of the system it was measured and calculated in terms of Partial Factor Productivity (PFP) $PFP_n = GY_n/F_n$ and Agronomic efficiency (AE) $AUE_n = (GY_n\text{-}GY_0)/F_n$ Where, (PFP_n and $AUE_{n)}$, are the partial factor productivity and agronomic use efficiency of N. In case of the GY_0 and GY_n are the yields of the respective treatments (control, N alone) and F_n are the amounts of nitrogen applied to particular treatment. The quantity of all nutrients input and economic outputs are expressed in kg ha^{-1}. Relative yield responses (RR) to different nutrient combinations were calculated by using the formula of [grain yield (treatment X) - grain yield (control)]/ grain yield (control) where, treatment X represents N, NP, NK and NPK application (Tittonell *et al.*, 2008). Marginal returns (MR) for the treatment over the control was calculated as $MR= [(NR_t\text{-}\ NR_c) / (CC_t\text{-}CC_c)] \times 100$, where NR_t and NR_c are Net returns of treatment and control respectively while CC_t and CC_c are cost of cultivation of treatment and control respectively. Regarding statistical analysis, each farmer experimental plot were considered as a replication at each location and randomized block design (RBD) was used for statistical comparisons. Descriptive statistical analysis was used for different parameters to establish the range of variability and deviation with in location using standard error of mean. Thereafter, the Randomized Block Design was used to compare treatment means within and between the locations.

Results and Discussion

Rice Equivalent System Yield (RESY)

In case of Rice –horse gram cropping system (RHCS) yield it was calculated in terms of rice equivalent system yield (Tanle-3). Rice – horse gram cropping system responded significantly positively with the addition of recommended quantity of N, P and K. Among all treatments application of balanced dose of fertilizers along with micronutrients (T_6) recorded highest rice equivalent system yield followed by the treatment T_5 and among the selected villages, Panhale village of Rajapur block recorded higher rice equivalent system yield (RESY) of 6105.2 kg/ha with recommended quantity of NPK with ZnSO4 application followed by village Asage in same block in case of Lanja block village Unhale (5817.2 kg/ha) followed by village Parule as Rajapur block is having higher productive soils compare to Lanja block. The higher levels of yield observed with application of NPK with ZnSO4 at all the locations. It may be due to the involvement of P in vigorous root development and proper absorption of N,

as K is involved in N metabolism in rice crop and P plays vital role in improving productivity of horse gram. Balanced NPK fertilizers application along with $ZnSO_4$ is an essential management practice for rice-horse gram system to achieve the higher productivity and profitability of the system, similar findings were reported by Ghosh *et al.,* (2004) and Prasad *et al.,* (2004) (Table 3).

Partial factor productivity (PFP)

Regarding partial factor productivity (Table 4) it was recorded at higher side with the treatment (T_6) balanced NPK fertilizers application along with $ZnSO_4$ as compared to application of nitrogen alone, combination of nitrogen + phosphorus, nitrogen + potassium and application of NPK in combination. Partial factor productivity of nitrogen (PFPn) can be increased from 48.02% to 43.79% in Kharif rice crop and 26.09 % to 24.44 % in horse gram crop when treatment T_6 was impose to the rice -horse gram cropping system as compared to application of nitrogen alone, combination of NP and combination of NK in rice- horse gram cropping system in all villages of study area. Appropriate balance of nutrients applied in soil play significant role in improving the recovery of NPK from applied fertilizers and from native soils it is obvious from the estimation of PPFn of rice-horse gram cropping system with application of balanced NPK fertilizers application along with $ZnSO_4$, similar findings were recorded by Haerdter and Fairhurst (2003).

Agronomic efficiency (AE)

Estimation of an incremental efficiency from applied Nitrogen, over control, was done in our study, it was noticed that apart from of fertilizer treatments, calculated agronomic use efficiency of applied N (AUE_n) is greater in rice than in horse gram at all locations (Table 5). In study area it was observed that farmers are habitual of applying only N fertilizers only. AUEn can be increased from 26.48% to 21.58% in Kharif rice crop and 15.58 % to 14.26 % in horse gram crop when treatment T_6 was impose to the rice -horse gram cropping system as compared to application of nitrogen alone, combination of NP and combination of NK in rice- horse gram cropping system in all villages of study area. Data indicated that application of NP or NK had recorded considerable increase in AUE of N at all the locations of study area as compared to application of N alone, the magnitude of increase in AUE was meager than the balanced application of NPK+micronutrient. Panwar *et al.,* (2019) recorded similar findings which are in conformity with results noted.

Relative response (RR)

Relative response (Table 6) of balanced application of nutrients along with micronutrients over control recorded similar results as that of PFP and AE. Relative response of application of NPK + deficient micronutrients over control was in the range of 0.98 to 1.24 these results are in conformity with the findings of (Ravisankar *et al.,* 2014) Among the all villages Parule location of block Lanja had recorded higher relative response of with NPK over control it might be due to the fact of effective resource utilization of nutrients. It is also evident from higher PPF to the rice-horse gram cropping system.

Marginal returns

In case of estimated cost of cultivation it was higher in treatment (T_6) balanced NPK fertilizers application along with ZnSO4 at all the locations of the study area and it was ranged from 117971.2 /ha in Unhale village of Rajapur block to 117089.7/ha in Asage village of Lanja block (Table 7).

Table.1 Particulars of farmers' fields with on-farm experiments at six village's locations in Ratnagiri district of Maharashtra

Characteristics	Lanja Block						Rajapur block					
	Veral		Asage		Panhale		Unhale		Parule		Shedhe	
	Rice	Horse gram	Rice	Horse gram	Rice	Horse gram	Rice	Horse gram	Rice	Horse gram	Rice	Horse gram
N	82.5	10	82.5	10	82.5	10	82.5	10	82.5	10	82.5	10
P	25	20	25	20	25	20	25	20	25	20	25	20
K	0	0	0	0	0	0	0	0	0	0	0	0
Zn	0	0	0	0	0	0	0	0	0	0	0	0
Soil texture	**Red ferruginous**		**Red ferruginous**		**Red ferruginous**		**Red ferruginous**		**Red ferruginous**		**Red ferruginous**	
pH	6.38		6.55		6.20		6.69		7.28		7.05	
OC (%)	0.51		0.66		0.41		0.64		0.81		0.65	
N (kg ha	249.63		225.79		233.32		219.52		283.49		270.95	
P (kg ha	11.65		9.58		9.68		10.19		11.99		11.47	
K (kg ha	195.71		177.25		158.43		190.43		195.71		186.39	

Table.2 Recommended levels of N, P, K, and Zn, genotype and date of transplanting of rice- horse gram cropping system in Ratnagiri district of Maharashtra

Location	Rice								Horse gram					
	Variety	Duration in days	Recommended Levels of Nutrients (kg ha ^{1})				Date of Transplanting	Variety	Duration in days	Recommended Levels of Nutrients				Date of sowing
			N	P	K	Zn				N	P	K	Zn	
Veral	Ratnagiri-4	125	100	50	50	20	16-Jully	Dapoli-1	100	25	50	0	0	16-November
Asage	Ratnagiri-4	125	100	50	50	20	18-Jully	Dapoli-1	100	25	50	0	0	18-November
Panhale	Ratnagiri-4	125	100	50	50	20	19-Jully	Dapoli-1	100	25	50	0	0	21-November
Unhale	Ratnagiri-4	125	100	50	50	20	15-Jully	Dapoli-1	100	25	50	0	0	17-November
Parule	Ratnagiri-4	125	100	50	50	20	05-Jully	Dapoli-1	100	25	50	0	0	15-November
Shedhe	Ratnagiri-4	125	100	50	50	20	06.Jully	Dapoli-1	100	25	50	0	0	22-November

Table.3 Effect of NPK and Zn on rice-horse gram cropping system on rice equivalent yield (SREY) kg/ ha^{-1} at farmer's field

Location	**System rice equivalent yield (SREY) Kg / ha**						
	control	N alone	With P	With K	With PK	With PK and Zn	FFMP
Veral	2900.2	3621.8	3880.4	3869.3	5072.4	5741.2	4436.8
Asage	2879.7	3684.9	4270.2	4107.0	4786.3	5889.0	4242.6
Panhale	2730.3	3693.1	4410.8	4201.7	4710.2	6105.2	4205.2
Unhale	2683.1	3810.6	4217.0	4183.9	5095.0	5817.2	4379.9
Parule	2784.9	3662.0	4041.1	3952.7	4881.0	5705.8	4355.9
Shedhe	2752.2	3731.2	4002.5	3938.3	4994.1	5638.8	4193.2

Table.4 Partial Factor Productivity (PFP) of nitrogen (kg grain kg ^{1} nutrient applied) of rice – Horse gram cropping system in Ratnagiri district of Maharashtra

Location	Kharif Rice						Horse gram					
	Partial Factor Productivity of N (PFP_n)											
	N alone	With P	With K	With PK	With PK and Zn	With FP	N alone	With P	With K	With PK	With PK and Zn	With FP
Veral	28.12	29.55	29.66	39.17	44.63	42.62	16.31	19.98	19.10	23.75	25.56	42.03
Asage	28.50	32.88	31.74	36.53	46.22	40.49	17.14	20.52	19.21	24.41	24.44	42.83
Panhale	28.64	34.14	32.63	36.23	48.02	40.07	16.81	20.37	18.93	22.75	24.84	42.94
Unhale	29.58	32.37	32.54	39.09	45.17	41.82	17.14	20.58	18.52	24.91	26.09	43.67
Parule	28.24	30.87	30.61	37.46	44.50	41.54	17.35	20.48	18.20	23.94	24.88	44.22
Shedhe	28.68	30.57	30.51	38.41	43.79	39.66	18.02	20.21	17.99	24.01	25.28	45.24

Table.5 Agronomic use efficiency (AUE) of Nitrogen (kg increased grain yield kg ^{1} nutrient applied) of rice – Horse gram cropping system in Ratnagiri district of Maharashtra

Location	Kharif Rice						Horse gram					
	Agronomic use efficiency (AUE) of N											
	N alone	With P	With K	With PK	With PK and Zn	With FP	N alone	With P	With K	With PK	With PK and Zn	With FP
Veral	5.06	6.50	6.60	16.11	21.58	14.67	5.63	9.30	8.42	13.08	14.89	15.34
Asage	5.50	9.87	8.74	13.53	23.22	12.61	6.96	10.34	9.03	14.23	14.26	17.38
Panhale	7.10	12.60	11.09	14.69	26.48	13.96	7.01	10.56	9.12	12.94	15.03	18.42
Unhale	8.45	11.24	11.41	17.96	24.04	16.21	6.63	10.06	8.01	14.40	15.58	17.38
Parule	5.94	8.56	8.30	15.16	22.19	14.50	7.16	10.29	8.01	13.75	14.69	18.74
Shedhe	6.86	8.75	8.69	16.59	21.97	13.22	7.90	10.09	7.87	13.89	15.16	19.95

Table.6 Relative response of treatments over control of rice – horse gram cropping system in Ratnagiri district of Maharashtra

Location	Relative response					
	N	NP	NK	NPK	With NPK and Zn	FP
Veral	0.25	0.34	0.33	0.75	0.98	0.53
Asage	0.28	0.48	0.43	0.66	1.05	0.47
Panhale	0.35	0.62	0.54	0.73	1.24	0.54
Unhale	0.42	0.57	0.56	0.90	1.17	0.63
Parule	0.31	0.45	0.42	0.75	1.05	0.56
Shedhe	0.36	0.45	0.43	0.81	1.05	0.52

Table.7 Effect of N, P, K, and Zn on cost of cultivation (Rs/ha) and gross returns (Rs/ha) of rice – Horse gram cropping system in Ratnagiri district of Maharashtra

Location	Cost of Cultivation (Rs/ha)							Gross Returns (Rs/ha)						
	Control	N	NP	NK	NPK	NPK Zn	FFM	Control	N	NP	NK	NPK	NPK Zn	FFM
Veral	82752.4	102243.7	110295.4	107550.8	115090.2	117817.0	103676.2	76566	114250	135396	131675	150949	162024	117062
Asage	82434.2	102211.9	110236.1	110389.5	115335.4	117089.7	103755.9	75035	113446	134179	130213	150628	158171	117736
Panhale	82305.2	102137.6	110522.2	107379.5	114542.8	117421.9	103914.3	74396	111024	136663	131368	145210	159194	118890
Unhale	82613.3	102205.8	110534.0	107061.4	115613.1	117971.2	104234.7	77883	113434	136471	128066	154886	163453	118331
Parule	82602.2	102101.6	110863.9	107690.1	115506.0	117242.3	103435.7	75420	112897	138923	133685	154257	157543	116593
Shedhe	82404.3	102421.1	110773.2	107390.1	115148.3	117271.3	103769.6	75573	117427	140682	131789	150317	156555	117929

Table.8 Effect of N, P, K, and Zn on net returns (Rs/ha) and B:C ratio of rice – Horse gram cropping system in Ratnagiri district of Maharashtra

Location	Net Returns (Rs/ha)							B:C Ratio						
	Control	N	NP	NK	NPK	NPK Zn	FFMP	Control	N	NP	NK	NPK	NPK Zn	FFMP
Veral	-6186.3	12006.5	25100.9	24124.0	35858.8	44206.9	13386.2	0.93	1.12	1.23	1.22	1.31	1.38	1.13
Asage	-7398.9	11234.0	23943.2	19823.5	35292.1	41080.9	13980.1	0.91	1.11	1.22	1.18	1.31	1.35	1.13
Panhale	-7909.0	8886.1	26140.7	23988.5	30667.4	41771.6	14975.9	0.90	1.09	1.24	1.22	1.27	1.36	1.14
Unhale	-4730.2	11228.2	25936.7	21004.9	39273.0	45482.1	14096.3	0.94	1.11	1.23	1.20	1.34	1.39	1.14
Parule	-7181.8	10795.8	28059.4	25994.6	38750.8	40300.3	13157.7	0.91	1.11	1.25	1.24	1.34	1.34	1.13
Shedhe	-6830.8	15006.2	29908.9	24398.5	35169.0	39283.3	14159.3	0.92	1.15	1.27	1.23	1.31	1.33	1.14

Table.9 Marginal returns (MR) (%) due to application of N with P and K over control in rice – horse gram cropping system in Ratnagiri district of Maharashtra

Location	Marginal returns (MR) (%)					
	N	NP	NK	NPK	With NPK and Zn	FP
Veral	93	114	122	130	144	34
Asage	94	113	97	130	140	31
Panhale	85	121	127	120	141	33
Unhale	81	110	105	133	142	43
Parule	92	125	132	140	137	29
Shedhe	109	130	125	128	132	34

Similar trend was noticed in case of net returns it was comparatively higher at all the locations with NPK application along with $ZnSO_4$ compared to control, N alone, NP, NK and NPK combinations. Marginal returns (Table 9) were found to be higher with combined application of NPK+ $ZnSO_4$ than N alone, NP, NK and NPK. Among the villages, Veral location of Lanja block recorded highest (144%) marginal returns under balanced application followed village Unhale of Rajapur block (142%) of rice –horse gram cropping system in study area. Application of N alone, NP, NK and NPK recorded lower marginal returns at all the location by reaming treatment as compared to balanced application of nutrients, these results are on same line ass by Raghuveer Singh *et al.*, (2017).

With aim to improve productivity, use efficiency and returns from rice-horse gram cropping system in the south konkan region an appropriate balanced application of recommended quantity of NPK with micronutrients is essential. Thus, it can be concluded that application of recommended quantity of nitrogen, phosphorus and potassium together with supplementation of location specific deficient micronutrient is essential for getting higher productivity, profitability and to have proper response to applied.

Acknowledgement

The authors are highly thankful to Indian Council of Agricultural Research-Indian Institute of Farming Systems Research, Modipuram, UP, India for financial help in conducting the trials on farmer's field.

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How to cite this article:

Dahiphale, A. V., S. B. Bhagat, N. V. Mhaskar, D. G. Jondhale, T. J. Bedse and Vanve, P. B. 2020. On-farm Assessment of Balanced Crop Nutrition on Productivity and Nutrient Use Efficiency in Rice (*Oryza sativa* L.) – Horse Gram [*Macrotyloma uniflorum* (Lam.) Verdc] Cropping System in South Konkan Coastal Zone of Maharashtra. *Int.J.Curr.Microbiol.App.Sci.* 9(05): 2250-2259. doi: https://doi.org/10.20546/ijcmas.2020.905.256