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Influence of Integrated Plant Nutrition System on Growth, Development and Yield of Wheat in Rice-Wheat Cropping System in Hilly Area of India

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The present investigation was undertaken in a long-term experiment on IPNS in rice-wheat cropping system at the Badiarkhar farm of CSK HPKV Palampur Himachal Pradesh. Twelve treatments *viz*., control (no fertilizer/manure), 50, 75 and 100% NPK each to rice and wheat through fertilizers, 50% NPK to rice and 100% NPK to wheat through fertilizers, 50% substitution of N through FYM, wheat straw and green manure in rice and 100% NPK through fertilizers in wheat; 25% substitution of N through FYM, wheat straw and green manure in rice and 75% NPK through fertilizers in wheat; and farmers' practice (40% NPK through fertilizers to each crop plus 5 t FYM/ha on dry weight basis to rice) were evaluated for a period of two years (2014-15 and 2015-16) with four replications. Increasing level of NPK application to wheat increased the number of shoots per metre square, maximum being in the treatment T_6 (50% NPK with 50% N through FYM to rice and 100% NPK was applied through fertilizers to wheat) and lowest in T_1 (control) during both years. Significantly more plant height of wheat was recorded when application of 100% NPK to each crop was made (T_5) during 2014-15 and 50% NPK with 50% N through FYM to rice and 100% NPK to wheat (T_6) during 2015-16. Shortest crop stature was recorded under T_1 (control) during both the years. The minimum days to flowering and maturity in wheat were in T_6 during both the years. T_6 gave significantly higher grain and straw yield of wheat during 2015-16. On an average T_6 where 50% NPK in combination with 50% N (FYM) was applied to rice and 100% NPK to wheat was found to be the best treatment for getting higher productivity and profitability. Treatments have significant effect on grain yield of wheat during 2015-16 and straw yield during both the years.

Introduction

Of the 30 major cropping systems identified in India (Yadav and Prasad, 1998), rice-wheat cropping system is the most predominant in India occupying around 10.5 m ha area (Sharma 2009). Among cereals, rice and wheat are the most important crops, which account for about 60% of world's human energy requirement. This system contributes about 75% of the nation's total food grain production, thus forms the backbone of food security (Lathwal *et al.*, 2010). Wheat occupies a principal place in the diet of humans globally, contributing more to our daily calorie and protein intake than any other crop (Meulen and Chauhan 2017). In India, total area under wheat is 30.9 mha with production of 93.5 mt (Anonymous 2016). It has tremendously helped the socio-economic development of the rural population in India. Farmers realize much of their food security from this cropping system. Besides food security, the low production levels jeopardize farmers' economic security to a considerable extent. The top most priority to meet the food demand of expanding human population is to increasing productivity of main grain crops. To strengthen the economic conditions of the farmers, it is imperative to sustain the productivity of this system. However, fertilizers are the kingpin in increasing crop productivity. But in case of intensive cultivation, growing exhaustive crops, use of unbalanced and inadequate fertilizers accompanied by restricted use of organic manures and biofertilizers have made the soils not only deficient in the nutrients, but also deteriorated in its health resulting in decline in crop response to the recommended dose of N-fertilizer. Under such a situation, integrated nutrient management (INM) has assumed a great importance and has vital significance for the maintenance of soil productivity. INM involving the use of fertilizers along with organic sources of nutrient such as FYM, GM and crop residues is a precious research outcome to restore productivity. INM, the managerial aspect of integrated plant nutrition system (IPNS) is more vital in sustaining increased productivity (Yadav and Kumar, 2009). The integrated use of organic manures and inorganic fertilizers can help to maintain optimum crop yields and long term soil productivity (Puli *et al.*, 2016). Farmers mostly use organic sources alone but their availability as per the requirement is a problem. The importance of leguminous green manure (GM) crops in improving soil fertility and soil physical properties has received increasing attention in recent past (Ray and Gupta 2001). Organic manures, particularly GM and farmyard manure (FYM), not only supply macronutrients but also meet the requirement of micronutrients, besides improving soil health.

Materials and Methods

Geographically, the experimental site is situated at 32°6^{0}N latitude, 76° 3^0 E longitude and 1223.7 m altitude in North Western Himalaya in the Palam Valley of Kangra district of Himachal Pradesh. The present study was undertaken during 2014 and 2015 in an ongoing long - term experiment which was initiated during kharif 1991 with rice - wheat cropping system at the Bhadiarkhar farm of CSK HPKV Palampur university. Palampur represents the sub-temperate humid zone of Himachal Pradesh which is characterized by mild summers and cool winters. The area receives a very high rainfall during monsoon and medium to high rainfall with an occasional snowfall during winters. Agro-climatically, the experimental site falls in the sub-temperate zone in the mid-hills of Shivalik ranges of Himalayas which is endowed with mild summers and cool winters along with high rainfall during south-west monsoons. Average rainfall at the experimental site is 2600 mm/annum, major portion of which (80%) is received during monsoon season (June to September). The soil of the experimental site was silty clay loam in texture, acidic in nature (pH 5.5), high in available nitrogen (675 kg/ha), medium in available P (22 kg/ha) and K (221 kg/ha) with CEC of 11.5 c mol (p±). Taxonomically the soils of the region are classified as 'Typic Hapludalf'. The field experiment was established with rice and wheat as test crops. In this field investigation, 12 treatments were evaluated in a randomized block design with four replications which are as follows (Table

1).

In farmers' practice, FYM 5 t/ha was applied along with 40% NPK to rice followed by 40% NPK to wheat. The recommended (100%) dose of nutrients in rice and wheat was 90:40:40 and 120:60:30 kg N, P_2O_5 and K_2O/ha, respectively. Samples of organic sources were analyzed for N, P and K contents as per the methods before application in rice season and data have been reported in Table 2. Quantity of farmyard manure (FYM), wheat cut straw (WCS) and *ex-situ* green manure (GM) used in the experiment were worked out on field weight basis and incorporated before transplanting of rice.

Crop studies

Growth studies

The observations on growth characters *viz.*, plant height and number of shoots (plant population) was recorded at monthly interval in wheat crop. For these observations, one outer row on all sides was left as border rows and the following one row on both sides were used for dry matter accumulation studies. The procedures adopted for recording of observations on various growth parameters are described here as under:

Plant height

Height of five randomly selected plants in the net plot area were measured from the soil surface to the tip of tallest leaf or tip of wheat spike and mean height was worked out.

Number of shoots

In case of wheat, 1m row length was marked with sticks at two observation units in the net plot area. Total numbers of shoots in metre row length was counted at intervals mentioned as above and mean value was converted to number of shoot/m^2 of rice and wheat.

Development studies (Phenophases)

Days to heading/flowering

In case of wheat the 1m row length marked for shoot counting was utilized for recording 75% heading stage. When 75% of the total shoots in 1m row length borne spikes, the date was noted as heading/flowering date. The number of days after sowing was worked out as days taken for heading/flowering.

Days to maturity

In case of wheat one metre row length was again utilized for recording maturity stage and when 75% of the grains attained hard dough stage, the date was noted as maturity stage and number of days required were worked out from date of sowing.

Results and Discussion

Crop-weather interaction

The performance of any crop depends on the interaction between genetic and environmental factors. The environment plays an important role in influencing growth, development and ultimately the yield of a crop. Among the various environmental factors, weather parameters like ambient temperature, rainfall, sunshine hours and relative humidity play an important role. In *rabi* 2014-15 and 2015-16 (November to May), average monthly maximum temperature ranged between 15.2 to 30.1 °C and 16.6 to 30.5°C, respectively (Fig. 1). The average monthly minimum temperature ranged between 4.0 to 17.6°C and 3.5 to 17.0°C in 2014 and 2015, respectively. It indicated that temperature during the crop cycle was favourable for germination, development and yield of wheat as ideal temperature range for successful wheat cultivation has been reported to be between 25 to 30°C (Arnon, 1972). The crop experienced well distributed rainfall of 367.2 mm and 682.9 mm in the first and second year, respectively which was in the optimum range of 360-630 mm (Reddy, 2004). The highest monthly total rainfall of 203.0 mm and 140.0 mm during the first and second year, respectively, was in March. The mean relative humidity during the crop season of first and second year was between 58 to 75% and 41 to 66%, respectively. The overall weather conditions were favorable for growth and development of wheat as well as rice.

Plant population (No./m^2)

Data on plant population at 90 DAS presented in Table 3 reveal that the increasing level of NPK application to wheat increased the number of shoots/m^2, maximum being in the treatment T_6 (50% NPK and 50% N through FYM to rice and 100% NPK was applied through fertilizers to wheat) and lowest in T_1 (control) during both years. Regulation of shoot/root growth under homogeneous N supply has been attributed to nutrient availability, particularly to N or C partitioning. However, T_6 did not produce significant difference from T_7 (75% NPK and 25% N through FYM to rice and 75% NPK to wheat), T_{10} (50% NPK and 50% N through GM to rice and 100% NPK to wheat), T_{11} (75% NPK and 25% N through GM to rice and 75% NPK to wheat) and T_{12} (Farmers' practice) during 2014-15. The results are in conformity with Parewa and Yadav (2014).

Plant height (cm)

Nitrogen element is the nutrient that most frequently limits yield and plays an important role in quality of crops. Significantly more plant height was recorded when application of 100% NPK to each crop was made (T_5) during 2014-15 and 50% NPK and 50% N through FYM to rice and 100% NPK to wheat (T_6) during 2015-16 (Table 3). Shortest crop stature was recorded under T_1 (control) during both the years. It is interesting to note that application of 100% NPK to both rice and wheat (T_5) had no significant difference with any treatment except T_1 (Control) and T_2 (50% NPK through chemical fertilizer) to each crop, in influencing plant height during 2014-15. T_6, however, produced significantly taller plants over all other treatments during 2015-16 when the difference from T_5 (100% NPK to each crop), T_7 (75% NPK and 25% N through FYM to rice and 75% NPK to wheat) and T_{11} (75% NPK and 25% N through GM to rice and 75% NPK to wheat) was not significant. Khoshgoftarmanesh and Kalbasi (2002); El-Gizawy (2009) had also obtained improved crop growth by the use of organic materials in the form of organic manure or FYM. Ibrahim *et al.,* (2008) have demonstrated the improvement of wheat growth and plant population with the use of organic manure and compost compared with chemical fertilizer. It is quite possible to get higher wheat yield by the integrated use of organic and inorganic fertilizers. Application of FYM was found to be responsible for improvement in different physiological characters in wheat *viz*., Chlorophyll- a, b content and heat stress tolerance of crop (Kowsar and Boswal, 2015). Increase in plant height and grain yield due to the increased levels of NPK fertilizers combined with FYM was reported by Parewa and Yadav (2014) and Kalhapure *et al.*, (2015).

Developmental stages

Perusal of data on days taken to flowering in Table 4 reveals that significantly lowest number of days (117) was recorded in T_6 (50% NPK and 50% N through FYM to rice and 100% NPK to wheat) both during 2014-15 and 2015-16.

Table.1 Details of treatments in rice-wheat cropping system

Treatment	*Kharif*	*Rabi*
T_1	Control (No fertilizer, no manures)	Control (No fertilizer, no manures)
T_2	50% NPK* through fertilizer	50% NPK through fertilizer
T_3	50% NPK through fertilizer	100% NPK through fertilizer
T_4	75% NPK through fertilizer	75% NPK through fertilizer
T_5	100% NPK through fertilizer	100% NPK through fertilizer
T_6	50% NPK+50% N through farmyard manure (FYM)	100% NPK through fertilizer
T_7	75% NPK+25% N through farmyard manure	75% NPK through fertilizer
T_8	50% NPK+50% N through wheat cut straw (WCS)	100% NPK through fertilizer
T_9	75% NPK+25% N through wheat cut straw	75% NPK through fertilizer
T_{10}	50% NPK+50% N through green manure (GM)	100% NPK through fertilizer
T_{11}	75% NPK+25% N through green Manure	75% NPK through fertilizer
T_{12}	Farmers' practice (40% NPK+ 5t FYM/ha)	Farmers' practice (40% NPK through fertilizer)

*NPK - Through chemical fertilizer

Table.2 Nitrogen, phosphorus and potassium contents (%) of organics (dry wt. basis)

Organics	N	P	K
FYM (Cow dung manure)	1.20	0.225	1.013
Wheat cut straw	0.46	0.048	1.300
Green manure (Dhaincha)	2.40	0.163	1.556

Table.3 Effect of treatments on plant population (No./m^2) and plant height (cm) of wheat

Treatment	Plant population		Plant height	
	2014-15	2015-16	2014-15	2015-16
T_1 - Control (No nutrients to each crop)	305.3	277.4	61.4	81.4
T_2 - 50% NPK* to each crop	318.7	327.4	79.7	86.9
T_3 - 50% NPK to rice & 100% NPK to wheat	334.4	330.0	85.1	86.0
T_4 - 75% NPK to each crop	351.2	367.8	88.6	86.6
T_5 - 100% NPK to each crop	352.5	390.0	92.0	91.6
T_6 - 50% NPK + 50% N (FYM*) to rice & 100% NPK to wheat	376.8	416.5	85.3	92.4
T_7 - 75% NPK + 25% N (FYM) to rice & 75% NPK to wheat	365.5	374.6	90.9	89.1
T_8 - 50% NPK + 50% N (WCS*) to rice & 100% NPK to wheat	351.9	331.2	87.3	84.8
T_9 - 75% NPK + 25% N (WCS) to rice & 75% NPK to wheat	344.8	346.4	89.3	84.0
T_{10} - 50% NPK + 50% N (GM*) to rice & 100% NPK to wheat	363.1	343.6	84.5	84.2
T_{11} - 75% NPK + 25% N (GM) to rice & 75% NPK to wheat	357.4	376.3	88.7	89.5
T_{12} - Farmers' practice	358.9	334.1	84.0	86.3
LSD (P=0.05)	23.8	24.8	8.8	4.9

*NPK- Through fertilizers, FYM- Farmyard manure, WCS- Wheat cut straw, GM- Green manure

Table.4 Effect of treatments on days taken to flowering and maturity in wheat

Treatment	Flowering		Maturity	
	2014-15	2015-16	2014-15	2015-16
T_1 - Control (No nutrients to each crop)	122	125	173	180
T_2 - 50% NPK* to each crop	120	123	161	169
T_3 - 50% NPK to rice & 100% NPK to wheat	120	123	164	171
T_4 - 75% NPK to each crop	120	123	164	172
T_5 - 100% NPK to each crop	119	122	158	166
T_6 - 50% NPK + 50% N (FYM*) to rice & 100% NPK to wheat	117	120	154	161
T_7 - 75% NPK + 25% N (FYM) to rice & 75% NPK to wheat	119	122	165	173
T_8 - 50% NPK + 50% N (WCS*) to rice & 100% NPK to wheat	120	123	169	177
T_9 - 75% NPK + 25% N (WCS) to rice & 75% NPK to wheat	120	123	166	174
T_{10} - 50% NPK + 50% N (GM*) to rice & 100% NPK to wheat	119	122	160	168
T_{11} - 75% NPK + 25% N (GM to rice) & 75% NPK to wheat	120	123	168	176
T_{12} - Farmers' practice	121	124	173	179
LSD (P=0.05)	0.88	2.59	0.50	1.34

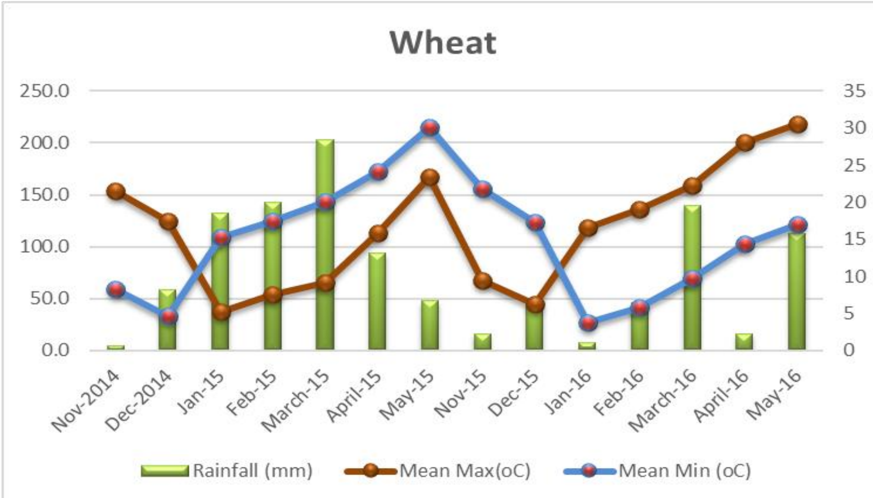
*NPK- Through fertilizers, FYM- Farmyard manure, WCS- Wheat cut straw, GM- Green manure

Table.5 Grain and straw yield (kg/ha) of wheat as affected by different treatments during 2014 and 2015

Treatment	Grain yield		Straw yield	
	2014-15	2015-16	2014-15	2015-16
T_1 – Control (No nutrients to each crop)	1101	1092	1947	3215
T_2 - 50% NPK* to each crop	1062	1392	3757	3660
T_3 - 50% NPK to rice & 100% NPK to wheat	1490	2830	3526	5054
T_4 - 75% NPK to each crop	1888	1978	4898	5193
T_5 - 100% NPK to each crop	2528	3105	4160	5521
T_6 - 50% NPK + 50% N (FYM) to rice & 100% NPK to wheat	2252	3485	4927	6295
T_7 - 75% NPK + 25% N (FYM) to rice & 75% NPK to wheat	1701	3018	5183	5275
T_8 - 50% NPK + 50% N (WCS) to rice & 100% NPK to wheat	1741	2691	5144	5048
T_9 - 75% NPK + 25% N (WCS) to rice & 75% NPK to wheat	2242	2422	4347	4843
T_{10} - 50% NPK + 50% N (GM) to rice & 100% NPK to wheat	1593	3039	4013	5541
T_{11} - 75% NPK + 25% N (GM to rice) & 75% NPK to wheat /	1446	2466	4849	5363
T_{12} - Farmers' practice	1397	2124	3914	3877
LSD (P=0.05)	NS	470	1160	968

*NPK- Through fertilizers, FYM- Farmyard manure, WCS- Wheat cut straw, GM- Green manure

Fig.1 Mean monthly weather data at Palampur (HP) for the period November 2014 and 2015 to May 2015 and 2016; rainfall, maximum temperature and minimum temperature



In the control wheat crop took significantly more number of days to attain 75% flowering over all other treatments during both the years.

Flowering and maturity in wheat (Table 4) were earlier in the plots manured with conjoint application of organics [FYM, green manure (dhaincha) and wheat cut straw] and fertilizers due to the direct and residual effects. Similar results were reported by Mehta (2004). This is because conjoint application of organics and chemical fertilizers resulted in early boost of vegetative growth due to better nutrition and thus, the attainment of physiological stages was enhanced. These findings are in agreement with Shah *et al.*, (2004).

Yield

The results pertaining to the effect of integrated nutrient supply on grain and straw yield of wheat (2014-15 and 2015-16) have been presented in Table 5. A perusal of the data revealed that different treatments had significant effect on grain yield of wheat during 2015-16 and straw yield during both the years. The higher yield was owed to improved growth and development and yield attributes. Wheat grain yield during second year (2015-16) ranged from 1092 kg/ha in control (T_1) to 3485 kg/ha in T_6 where 50% NPK through chemical fertilizer and 50% N through FYM to rice and 100% NPK to wheat through wheat cut straw during *kharif*. Farmers' practice too showed a significant increase (48.6%) over the control in wheat grain yield.

Chemical fertilizers alone or in conjunction with organic materials significantly increased straw yield of wheat. The straw yield varied from a minimum of 2410 and 3295 kg/ha in T_1 (Control) to a maximum of 7194 and 7688 kg/ha in T_6 (50% NPK through fertilizer with 50% N through FYM to rice and 100% NPK through fertilizer to wheat). On comparing the treatments consisting of organic materials, it was observed that T_7 (75% NPK through fertilizer with 25% N through FYM to rice and 75% NPK through fertilizer to wheat), T_{10} (50% NPK through fertilizer in combination with 50% N through GM to rice and 100% NPK through fertilizer to wheat) and T_{11} (75% NPK through fertilizer with 25% N through GM to rice and 75% NPK through fertilizer to wheat) were at par with

T_6 (50% NPK through fertilizer with 50% N through FYM to rice and 100% NPK through fertilizer to wheat), the increase was higher under FYM followed by GM and lowest in case of WCS. An increase of 10.0% and 18.7% in wheat straw yield was also recorded under farmers' practice (T_{12}), over control during 2014-15 and 2015-16, respectively. The omission of chemical fertilizers and organic manures for last 23-24 years (control) resulted in low yield due to continuous mining of nutrients. The integrated use of chemical fertilizers with organic manures *viz.*, farmyard manure (FYM), wheat cut straw (WCS) and green manure (GM) obviously added nutrients to meet out the nutrients demands of the crops. Sarwar (2005) who reported that yield and different yield parameters of rice increased significantly with the use of chemical fertilizers alone or in combination with various organic materials applied in the form of *Sesbania* green manure,

FYM and compost in field and pot experiments (Kaur and Verma 2016). FYM is a product of microbial activity and contains large number of microbial population. Application of FYM can increase the microbial activity in the soil both by activating the microbial action and by aiding the multiplication of microbial population.

Due to these properties, application of FYM is in perfect tune with biological requirement of soil and helps to build the soil on sustainable basis. The capacity of soil to release, store and supply the plant nutrients is based on this microbial activity of soil. Large number of reports is available in the literature to show the enhanced microbial activity by application of FYM. Increased organic carbon by application of FYM has been reported to help in increased population of bacteria, actinomycetes and fungi (Upadhyay and Vishwakarma, 2014; Mitran *et al.*, 2015; Gaind and Singh, 2015).

Wheat grain yield and straw yield during second year (2015-16) shows significant improvement in comparison to previous year. This could be attributed to more nutrient mobilization. T_6 treatment where 50% NPK through chemical fertilizer and 50% N through FYM to rice and 100% NPK to wheat through wheat cut straw during *kharif* was provided, was found better among all treatments.

In conclusion, this study highlights the impact of INM on growth, development and yield of wheat in rice-wheat cropping system. Treatment 6 (T6) performs better than other treatments which underlines the significance of INM in growth and development of crop. Flowering was earliest in T6 (50% NPK and 50% N (FYM) to rice and 100% NPK to wheat. The maturity of wheat was also significantly affected by fertilizer treatments. Grain yield, straw yield of wheat was highest under the treatment (T6) where 50% NPK and 50% N through FYM to rice and 100% NPK through fertilizer to wheat was applied.

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