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ENHANCING RICE AND WHEAT PRODUCTIVITY THROUGH RHIZOSPHERE ACTIVE HIGH YIELD TECHNOLOGY MICROBIAL PRODUCT

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ABSTRACT

Field experiments were conducted during both kharif and rabi seasons (2010-11 to 2012-13) to study the root parameters,yield, attributes,yields and nutrient use efficiency (partial factor productivity) under rice (*Oryza sativa* L) wheat (*Triticum aestivum* L.) cropping system. The experiment was laid out in randomized block design with seven treatments in three replications. The results indicated that recommended NPK (N_{120} P_{60} K_{40}) with higher dose of HYT A+B+C increased the growth, yields and yield parameters. Rice grain yield in $N_{120}P_{60}$ K_{40} with higher dose of HYT A+B+C was recorded significantly higher of the order of 4474, 5556 and 6462kg/ha during all three years 2010, 2011 and 2012, respectively which was 10.9, 8.5 and 13.5 % higher during the respective years over the recommended NPK dose of fertilizer ($N_{120}P_{60}K_{40}$). Similarly, wheat grain yield in $N_{120}P_{60}K_{40}$ with higher dose of HYT A+B+C was significantly higher emanating 25.8, 29.9 and 25.3% higher yield in 2010-11, 2011-12 and 2012-13, respectively over recommended NPK treatment. It can be summarized that application of recommended NPK with higher dose of HYT A+B+C exhibited best results in both rice and wheat in terms of root volumes, yields and yield parameters and partial factor productivity over three consecutive years of experimentation.

INTRODUCTION

Rice forms staple food for more than half of the world population and is also the hub of food security of global population. At global level, rice is grown in an area of about 155.62 million hectare with production and productivity of 461 million tonne and 4.09 t/ha, respectively. India ranks first in respect of area (44.5mha), second in production (102.75 mt), only after china, but the productivity of rice is very low only 2.20t/ha (Anonymous, 2012). The demand for rice in India is projected at 128 million tonnes (mt) for the year 2012 and will require a production level of 3,000 kg/ha significantly greater than the present average yield of 1,930 kg/ha (Tiwari, 2002). Total food grain production has followed the ups and downs of rice production in India. Yields must continue to increase by one percent per annum until 2020 (Rosegrant *et al.*, 1995) to keep up with demand. A major challenge during the coming decade is to develop cost effective technology transfer methods to increase the ability of farmers to manage the resources at their disposal more efficiently. The adoption of modern farming practices with the use of high yielding technology product is therefore, essential to produce crop in line with the observed global standards of quantity and quality.

The rhizosphere active High Yield Technologies (HYT) targeted solutions are made up of components, while the formulations, application rates and use methods of these components vary by targeted solution and they share a general set of attributes that provide proven benefits to the farmer. HYT product especially for agriculture has been formulated for high concentrations of conventional fertilizer, short crop cycles and regulated environmental conditions. This solution formula is focused on increasing nutrient availability to crop plants and improving mineral fertilizer efficiency. The main HYT product (HYT-A) is made of diverse and naturally occurring soil microorganisms and supported by other HYT products which include amino acids, chitin, chitosan and the derivatives (Sarim, 2013).

HYT with its in build soil amelioration properties contributed by beneficial microbes was expected to improve the soil and thus enable the release of the said locked nutrient by enabling the efficient absorption of nutrients by the plant at the time and in the quantities that the plant requires. To achieve this, HYT has two key components that are mixed together on site prior to application. HYT efficiency (HYT-A) is an organic live microbial formula that affects crop growth through the processing and presentation of essential nutrients to crop roots. HYT Efficiency's microbial ecosystem also works to restore a healthy soil. In addition to processing primary and secondary crop nutrients, repeated use of HYT Efficiency improves soil tilth and softens hardpan, increasing moisture retention, preventing water run-off and enabling the plant- root system to access sources of nutrients and moisture in deeper soil layers. HYT-A works by introducing a live microbial culture to the root area of the plant that metabolizes and presents key nutrients to the crops as the crops needs them (Agrinos, 2011). HYT Nutrition (HYT-B) is an organic, biologically extracted liquid amino acid and mineral nutrient solution which is a bio-stimulant and nutrition and stress-relief source consisting of free L-amino acids and trace minerals. It is constituted of 12 % L- free amino acids of L-tryptophan, L-aspartic acid, L-proline, L-tyrosine, L-arginine, l-valine, L-methionine, L-isoleucine, L-phenylalanine (Agrinos, 2011). By providing the plant with the L-amino acids it normally increases stress resistance, increases and supports photosynthesis, pollination and fruit set, stimulates vitamin formation and increases sugar content (Adu, 1992). HYT Protection (HYT-C) consists of organic, biologically-extracted micronized chitin. This high-grade natural polymer is used by the plant to strengthen root formation and cell structures. More importantly, HYT Protection provides preventative, natural, non-toxic soil based fungus and nematode control, safe for humans, plants and the environment. But studies on their effect on crop performance in the field in term of yield are meager (Agrinos, 2011). It is, therefore, hypothesized that good crop productivity can be achieved through HYT leading to higher crop yield. Taking all these points into consideration, the present experiment was planned to evaluate the crop productivity and nutrient use efficiency of rice-wheat system through the use of rhizosphere active high yield technology organic products.

MATERIALS AND METHODS

Field experiments were conducted on sandy loam soil at Norman E. Borlaug Crop Research Centre of G.B. Pant University of Agriculture and Technology, Pantnagar (Uttarakhand) in both *Kharif and Rabi* seasons during 2010 to 2012. The experiment was laid out in randomized block design replicated three times. The treatments combinations *viz.*, N_{120} P_{60} K_{40} (recommended NPK) dose at the time of sowing (T_1), N_{120} P_{60} K_{40} + soil application of HYT-A@ 1.0 l/ha at the time of sowing (T_2), recommended $N_{120}P_{60}$ K_{40} + HYT-A@1.0 l/ ha + HYT-C@ 2kg/ha as soil application at sowing (T_3), recommended N_{120} P_{60} K_{40}+ HYT-A@1.0 l/ha + HYT-B @2.0 l/ha at the time of flower initiation/ panicle initiation+ HYT-C@2 kg/ha as soil application at sowing (T_4), N_{60} P_{30} K_{20} dose + HYT-A@ 1.0 l/ha + foliar application of HYT-B@ 2l/ha + HYT-C@2kg/ha as soil application at sowing (T_5), N_{120} P_{60} K_{40} + soil application of HYT-A@ 2.0 l/ha + foliar application of HYT-B@ 5.0 l/ha + HYT-C@ 5kg/ha at sowing (T_6) and N_{120} P_{60} K_{40} + 1.0 l/ha of Shriram Suryamin as foliar application each at tillering and at flower initiation (T_7) during 2010-2012. HYT- A was activated with water at the ratio 1: 20 for 72 hours and applied to puddled fields at the time of transplanting in rice with sprayer having nozzle settings adjusted for correct flow rate and set to provide the minimum amount of product atomization and at the time of field preparation in wheat, HYT-C were applied directly without activation to field with the help of sprayer, HYT-B was applied as one foliar spray at panicle/ flower initiation time in both rice and wheat crops, respectively.

Rice varieties Pant Dhan-12 and PA-6444 and wheat variety PBW-550 were used for experimentation. Rice nursery was raised as per the standard and 20-25 days old rice seedlings of Pant Dhan-12 (during 2010 and 2011) and PA-6444 (during 2012) were transplanted at 20cm×10cmon 26 July 2010, 27 June 2011 and 6 July 2012, respectively. Fertilizers were applied at recommended dose of NPK i.e. 120:60:40 during three years with the help of urea (46%N) and NPK mixture (10:26:26). Nitrogen was given in two split doses i.e. half of recommended nitrogen with full phosphorus and potassium as basal (before transplanting) and rest half of nitrogen was applied at 20-25 & 40-45days after transplanting i.e. at active tillering and panicle initiation period. Weed control in rice was done with the application of Butachlor 33 EC@3.6 *a.i.* /ha at 3-5 days after transplanting and 1-2 hand weeding was done at 25-30 days interval as required. However, in wheat crop Pendimethalin was applied @ 1.0 a.i/ha followed by one hand weeding after first irrigation i.e. 25-30 DAS. For pest and disease control, management practices were adopted as per recommendations for this region. The data on root volume was taken at 60 DAT during 2010-11 & at harvest during 2012, dry mater, yield and yield attributes were recorded on net plot area during both the seasons. Data pertaining to root volume and root weight was recorded by selecting two hills of average vigour from second row of plot boundary. For this, two hills were dugout separately from a depth of 20 cm along with soil mass with 10 cm distance (20× 10cm spacing). The root portion of plants along with the soil mass was put in a fine –meshed plastic/ nylon bag and was immersed in a running water so that soil mass gets sufficiently loosened and all the roots were recovered and then cut off from the shoots. The fresh and cleaned roots of each plant were put separately in a graduated measuring cylinder partially filled with clean water and the rise in water level in the cylinder due to immersion of roots as root volume. The root volume of two hills was averaged out to get root volume/hill. Thereafter, these roots were separately dried in a oven at 70 ± 2°C until constant weight for noted obtaining root dry weight. Nutrient Use Efficiency in terms of Partial Factor Productivity (PFP) was also calculated for different treatments as per standard formulae (Cassman *et al.,* 1996).

PFP_N = Yield from N fertilized Plot (Kg/ha) / Amount of N applied (Kg/ha)

Data collected from various observations was subjected to the 'Analysis of Variance' appropriate to the design as given by Gomez and Gomez (1984). Test of significance of the treatment differences was done on the basis of F- test (Variance -ratio). Standard error of mean is computed in all cases. The significance difference between treatments means were compared with the help of critical difference at 5 per cent level of probability.

RESULTS AND DISCUSSION

Plant growth (rice)

All the growth characters *viz.* root volume and root dry weight

Table 1: Effect of different HYT organic products on plant growth of rice during 2010-2012.

Treatment	Root volume(cm^3)			Root dry weight (g)		
	2010	2011	2012	2010	2011	2012
	(60 DAT)	(60 DAT)	(At harvest)	(60 DAT)	(60 DAT)	(At harvest)
T_1: N_{120} P_{60} K_{40} (Rec. NPK)	28.0	24.67	60.7	6.8	5.2	27.6
T_2: N_{120} P_{60} K_{40} + HYT-A @ 1.0 l/ha	34.0	33.67	66.7	10.7	7.2	29.7
T_3: N_{120} P_{60} K_{40} + HYT-A@ 1.0 l/ha + HYT C@ 2.0 kg/ha	29.3	27.67	69.3	8.6	5.5	30.2
T_4: N_{120} P_{60} K_{40} + HYT-A@ 1.0 l/ha +HYT-B@ 2.0 l/ha +HYT-C@ 2.0kg/ha	34.6	32.50	72.8	9.8	6.6	33.2
T_5: N_{60} P_{30} K_{20}+ HYT-A@ 1.0 l/ha +HYT-B@ 2.0 l/ha +HYT-C@ 2.0kg/ha	31.0	16.50	52.7	8.5	3.9	20.5
T_6: N_{120} P_{60} K_{40}+ HYT-A@ 2.0 l/ha +HYT-B@ 5.0 l/ha +HYT-C@ 5.0kg/ha	37.0	35.00	89.3	11.7	7.5	36.0
T_7: N_{120} P_{60} K_{40} + Suryamin (two spray)	27.6	21.0	63.3	6.5	5.2	26.6
SEm+	2.6	2.01	3.77	1.0	0.61	2.61
CD at 5%	7.8	5.89	11.01	3.0	1.78	7.62

Table 2: Effect of different HYT organic products on yield attributes of rice during 2010-2012.

Treatment	Effective tillers/m^2			Grain weight/panicle (g)			Grain yield (kg/ha)		
	2010	2011	2012	2010	2011	2012	2010	2011	2012
T_1: N_{120} P_{60} K_{40} (Rec. NPK)	208	336	210	2.08	2.37	2.92	4036	5122	5692
T_2: N_{120} P_{60} K_{40} + HYT-A @ 1.0 l/ha	211	353	223	2.17	2.27	3.13	4259	5482	6188
T_3: N_{120} P_{60} K_{40} + HYT-A@ 1.0 l/ha + HYT C@ 2.0 kg/ha	207	323	214	2.01	2.32	3.26	3887	5232	6212
T_4: N_{120} P_{60} K_{40} + HYT-A@ 1.0 l/ha + HYT-B@ 2.0 l/ha +HYT-C@ 2.0kg/ha	212	342	228	2.17	2.32	3.24	4213	5353	6418
T_5: N_{60} P_{30} K_{20}+ HYT-A@ 1.0 l/ha + HYT-B@ 2.0 l/ha +HYT-C@ 2.0kg/ha	183	295	202	1.95	2.29	2.87	3330	4453	5045
T_6: N_{120} P_{60} K_{40}+ HYT-A@ 2.0 l/ha + HYT-B@ 5.0 l/ha +HYT-C@ 5.0kg/ha	218	358	227	2.20	2.42	3.32	4474	5556	6462
T_7: N_{120} P_{60} K_{40}+ Suryamin (two spray)	205	331	213	2.10	2.39	3.40	4018	5256	5963
SEm+	3.6	10.2	2.43	0.04	0.09	0.097	113	151	150
CD at 5%	10.6	29.8	7.10	0.12	NS	0.28	330	444	426

of rice roots increased significantly under recommended NPK+ HYT-A+B+C at higher dose over recommended NPK during all the years of experimentation. Significantly higher root volume (37cm^3)was observed in N_{120} P_{60} K_{40} + HYT-A+B+C at higher dose (T_6) which was *at par* with all the treatments except N_{120} P_{60} K_{40} (T_1) and N_{120} P_{60} K_{40} + Suryamin(T_7) in the year 2010, but in the year 2011was *at par* with N_{120} P_{60} K_{40} + HYT-A @ 1.0 l/ha (T_2), N_{120} P_{60} K_{40} + HYT-A@ 1.0 l/ha + HYT C@ 2.0 kg/ha (T_3) and N_{120} P_{60} K_{40} + HYT-A@ 1.0 l/ha +HYT-B@ 2.0 l/ha +HYT-C@ 2.0kg/ha (T_4). However under N_{120} $P_{60}K_{40}$(T_1), root volume (89.3 cm^3) was signifiantly higher over all other treatments in 2012.

The root dry weight of rice (11.7g, 7.5g and 36.0g) was significantly higher in N_{120} P_{60} K_{40} + HYT-A+B+C (higher dose) (T_6) during three years*i.e.*,2010, 2011 and 2012 respectively, which was *at par* with N_{120} P_{60} K_{40} + HYT-A @ 1.0 l/ha (T_2) andN_{120} P_{60} K_{40} + HYT-A@ 1.0 l/ha +HYT-B@ 2.0 l/ha +HYT-C@ 2.0kg/ha (T_4) during both 2010 and 2011. However in 2012, it was *at par* with N_{120} P_{60} K_{40} + HYT-A @ 1.0 l/ha (T_2), N_{120} P_{60} K_{40} + HYT-A@ 1.0 l/ha + HYT-C @ 2.0 kg/ha (T_3) and N_{120} P_{60} K_{40} + HYT-A@ 1.0 l/ha +HYT-B@ 2.0 l/ha +HYT-C @ 2.0kg/ha (T_4) (Table 1).

Vanitha and Das (2014) also reported that root volume was higher when humic acid was applied with recommended dose of NPK in aerobic rice. In a similar finding of Fageria and Baligar (2005) and Fageria (2009) , it was observed that overall root dry weight was 97% higher at the higher N rate (300 mg N/kg) compared to lower N rate (0 mg N/kg) and reported that N fertilization improved root dry weight in crop plants, including upland rice.

Yield attributes of rice

Effective tillers/m^2(218 and 358) were significantly higher in N_{120} P_{60} K_{40} + HYT-A+B+C at higher dose (T_6) during 2010 and 2011, respectively which was *at par* with N_{120} P_{60} K_{40} (T_1), N_{120} P_{60} K_{40} + HYT-A @ 1.0 l/ha (T_2) and N_{120} P_{60} K_{40} + HYT-A@ 1.0 l/ha +HYT-B@ 2.0 l/ha +HYT-C@ 2.0kg/ha (T_4). However significantly higher effective tillers/m^2(228) in 2012 was observed in N_{120} P_{60} K_{40} + HYT-A@ 1.0 l/ha +HYT-B@ 2.0 l/ha +HYT-C@ 2.0kg/ha (T_4) which was *at par* with N_{120} P_{60} K_{40} + HYT-A @ 1.0 l/ha (T_2) and in N_{120} P_{60} K_{40} + HYT-A+B+C at higher dose (T_6) (Table 2).

Similar work of Manzoor *et al.* (2006)on rice revealed that plants produced more number of productive tillers per hill (23.42) where 225 kg nitrogen per hectare was applied which remained statistically *at par* with that obtained by nitrogen application levels between 125 to 200 kg per hectare.These results are in line with those reported by Singh and Sharma (1987), Maqsood (1998), Nawaz (2002) and Meena *et al.*(2003). Enhanced tillering by increased nitrogen application might be attributed to more nitrogen supply to plant at active tillering stage.

Grain weight/panicle (2.20g and 2.42g) in 2010 and 2011, respectively was significantly higher in N_{120} P_{60} K_{40} + HYT-A@ 2.0 l/ha +HYT-B@ 5.0 l/ha +HYT-C@ 5.0kg/ha (T_6) which was *at par* with all the treatments except N_{120} P_{60} K_{40} + HYT-A@ 1.0 l/ha + HYT C@ 2.0 kg/ha (T_3) and N_{60} P_{30} K_{20}+ HYT-A@ 1.0 l/ha +HYT-B@ 2.0 l/ha +HYT-C@ 2.0kg/ha (T_5) in

Table 3: Effect of different HYT organic products on yield and yield attributes of wheat.

Treatment	Effective Tillers/m^2			Grain weight/spike			Grain yield(kg/ha)		
	2010	2011	2012	2010	2011	2012	2010	2011	2012
T_1: N_{120} P_{60} K_{40} (Rec. NPK)	268	270	272	1.37	1.77	1.69	3200	3917	3751
T_2: N_{120} P_{60} K_{40} + HYT-A @ 1.0 l/ha	255	278	276	1.60	1.81	1.71	3399	4680	4158
T_3: N_{120} P_{60} K_{40} + HYT-A@ 1.0 l/ha + HYT C@ 2.0 kg/ha	288	289	284	1.73	1.80	1.80	3790	4677	4362
T_4: N_{120} P_{60} K_{40} + HYT-A@ 1.0 l/ha +HYT-B@ 2.0 l/ha +HYT-C@ 2.0kg/ha	275	288	294	1.60	1.85	1.89	3580	4837	4522
T_5: N_{60} P_{30} K_{20}+ HYT-A@ 1.0 l/ha + HYT-B@ 2.0 l/ha +HYT-C@ 2.0kg/ha	243	284	264	1.17	1.53	1.56	2713	3577	3548
T_6: N_{120} P_{60} K_{40} + HYT-A@ 2.0 l/ha + HYT-B@ 5.0 l/ha +HYT-C@ 5.0kg/ha	295	290	296	1.57	1.99	1.90	4027	5087	4700
T_7: N_{120} P_{60} K_{40} + Suryamin (two spray)	265	290	277	1.70	1.96	1.71	3317	5060	4084
SEm ±	14.05	29.66	6.80	0.12	0.03	0.54	0.92	2.71	2.09
CD at 5%	NS	86.99	19.84	0.34	0.08	0.16	2.71	7.95	6.11

2010, but in 2011 it was *at par* only with N_{120} P_{60} K_{40} (T_1) and N_{120} P_{60} K_{40} + Suryamin(T_7). However in 2012, significantly higher grain weight/panicle (3.40g) was recorded in N_{120} P_{60} K_{40} + Suryamin(T_7) which was *at par* with all the treatments except N_{120} P_{60} K_{40} (T_1) and N_{60} P_{30} K_{20}+ HYT-A@ 1.0 l/ha +HYT-B@ 2.0 l/ha +HYT-C@ 2.0kg/ha (T_5)(Table 2).

Test weight (24.8g) was maximum in N_{120} P_{60} K_{40} + HYT-A+B+C at higher dose (T_6) and minimum (23.8g) in N_{60} P_{30} K_{20}+ HYT-A@ 1.0 l/ha +HYT-B@ 2.0 l/ha +HYT-C@ 2.0kg/ha (T_5) during 2010 but in 2011, test weight was highest(27.5g) in N_{120} P_{60} K_{40} + HYT-A@ 1.0 l/ha + HYT C@ 2.0 kg/ha (T_3) whereas least (22.2g) in N_{120} P_{60} K_{40} (T_1). In 2012, highest test weight (23.2g) was reported in N_{120} P_{60} K_{40} + HYT-A@ 1.0 l/ha +HYT-B@ 2.0 l/ha +HYT-C@ 2.0kg/ha (T_4) and least (22.6g) was reported in N_{120} P_{60} K_{40} (T_1) (Table 2).

Elevated nitrogen level had little impact on grain size of rice (Razzaque *et al.*, 2011).Individual grain weight is a fairly stable character in rice (Yoshida, 1981) and itis mostly determined genetically. The size of the husk is determined as early as 5days before flowering, which is very difficult to change by management (Murata and Matsushima, 1978). In a similar finding thousand grain weight in all the treatments differed significantly from one another and the highest thousand grain weight (18.8 g) was obtained from the plots fertilized by super net. (Chaturvedi, 2005).

Rice grain yield

Yield of rice during three years 2010, 2011 and 2012 was significantly affected by all the treatments. Highest grain yield (4474kg/ha, 5556kg/ha and 6462kg/ha)in 2010, 2011 and 2012, respectively was recorded in N_{120} P_{60} K_{40} + HYT-A @ 2.0 l/ha +HYT-B @ 5.0 l/ha +HYT-C @ 5.0kg/ha (T_6) which was *at par*with N_{120} P_{60} K_{40} + HYT-A @ 1.0 l/ha (T_2) and N_{120} P_{60} K_{40} + HYT-A @ 1.0 l/ha +HYT-B @ 2.0 l/ha +HYT-C @ 2.0kg/ha (T_4) during the year 2010, which was also *at par* with all the treatments except N_{60} P_{30} K_{20}+ HYT-A @ 1.0 l/ha + HYT-B @ 2.0 l/ha +HYT-C @ 2.0kg/ha (T_5) in 2011 whereas in 2012 it was only *at par* with N_{120} P_{60} K_{40} + HYT-A @ 1.0 l/ha (T_2), N_{120} P_{60} K_{40} + HYT-A @ 1.0 l/ha + HYT C @ 2.0 kg/ha (T_3) and N_{120} P_{60} K_{40} + HYT-A @ 1.0 l/ha +HYT-B @ 2.0 l/ha +HYT-C @ 2.0kg/ha (T_4)(Table 2).

Similar findings of Uddin *et al.* (2013) and Chaturvedi (2005)suggested that on increasing nitrogen along with potassium increased rice grain yield and yield components with the highest grain yield (3.49 t ha^{-1}) at 80 kg N ha^{-1} and40 kg K_2O ha^{-1} as potassium source.It therefore seems that the application of nitrogen increased the protein percentage, which in turn increased the grain weight.Kausar *et al* (1993) also reported similar result which reveals that grain weight is a genetically controlled trait, which is greatly influenced by environment during the process of grain filling.

In general, Yoshida (1981) believed that grain yield in rice is the product of different yield components. Also, Singh *et al.* (1998) showed that the relative importance of each component varies with location, season, crop duration and cultural system. Increase in grain yield could also be explained by the fact that root growth and absorption capacity were increased when 400 mg N kg^{-1} was applied(Mehdi and Dedatta, 1997).

The important issue for achieving a high yield in rice is enhancing the grain number with a high proportion of ripened grains (Fisher *et al.*, 1977). The increase in growth and yield owing to the application of N-fertilizers may beattributed to the fact that these nutrients being importantconstituents of nucleotides, proteins, chlorophyll andenzymes, involve in various metabolic processes whichhave direct impact on vegetative and reproductive phasesof plants (Mengel and Kirkby, 1996).

Yield attributes of wheat

Effective tillers/m^2 (295) were maximum in N_{120} P_{60} K_{40} + HYT-A@ 2.0 l/ha +HYT-B@ 5.0 l/ha +HYT-C @ 5.0kg/ha (T_6) and minimum in N_{60} P_{30} K_{20}+ HYT-A @ 1.0 l/ha +HYT-B @ 2.0 l/ha +HYT-C @ 2.0kg/ha (T_5) during 2010. Whereas effective tillers/m^2 (290 and 296) during 2011 and 2012, respectively were significantly higher in N_{120} P_{60} K_{40} + HYT-A @ 2.0 l/ha +HYT-B @ 5.0 l/ha +HYT-C @ 5.0kg/ha (T_6) which was *at par* with all the treatments in 2011. However it was *at par* with N_{120} P_{60} K_{40} + HYT-A @ 1.0 l/ha + HYT-C @ 2.0 kg/ha (T_3), N_{120} P_{60} K_{40} + HYT-A @ 1.0 l/ha +HYT-B @ 2.0 l/ha +HYT-C @ 2.0kg/ha (T_4) and N_{120} P_{60} K_{40} + Suryamin(T_7) in 2012 (Table 3).

Grain weight/spike (1.73g) was significantly higher in N_{120} P_{60} K_{40} + HYT-A @ 1.0 l/ha + HYT-C @ 2.0 kg/ha (T_3) during 2010 which was *at par* with all the treatments except P_{60} K_{40}

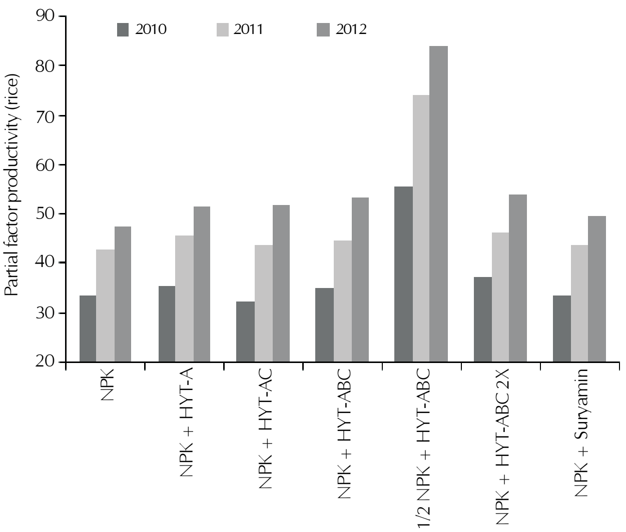

Figure 1: Effect of different HYT organic products on partial factor productivity of rice

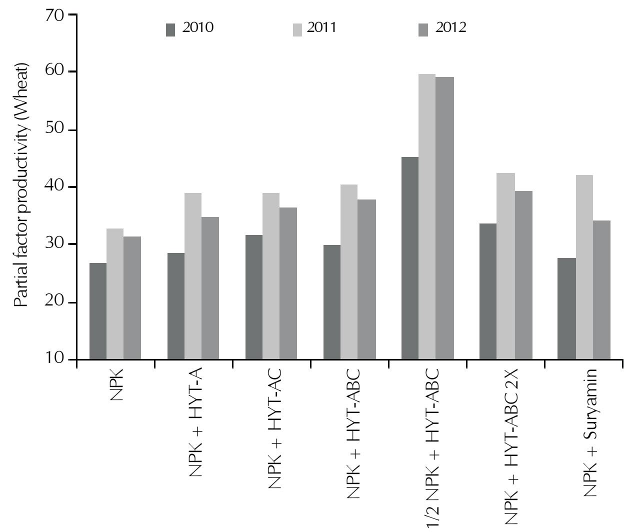

Figure 2: Effect of different HYT organic products on partial factor productivity of wheat

(T_1) and N_{60} P_{30} K_{20}+ HYT-A @ 1.0 l/ha +HYT-B @ 2.0 l/ha +HYT-C @ 2.0kg/ha(T_5). Whereas in 2011 and 2012, grain weight/spike (1.99g and 1.90g, respectively) was significantly higher in N_{120} P_{60} K_{40} + HYT-A @ 2.0 l/ha +HYT-B @ 5.0 l/ha +HYT-C@ 5.0kg/ha (T_6) which was *at par* with N_{120} P_{60} K_{40} + Suryamin(T_7) in 2011 and with N_{120} P_{60} K_{40} + HYT-A @ 1.0 l/ ha + HYT-C @ 2.0 kg/ha (T_3) and N_{120} P_{60} K_{40} + HYT-A @ 1.0 l/ha +HYT-B @ 2.0 l/ha +HYT-C @ 2.0kg/ha (T_4) in 2012 (Table 3).

Wheat grain yield

Wheat yield followed similar trend to rice yield. Here also significantly higherwheat grain yield (4027kg/ha, 5087kg/ha and 4700kg/ha)in 2010, 2011 and 2012, respectively was observed in N_{120} P_{60} K_{40} + HYT-A @ 2.0 l/ha +HYT-B@ 5.0 l/ ha +HYT-C @ 5.0kg/ha (T_6) which was *at par* with N_{120} P_{60} K_{40} + HYT-A @ 1.0 l/ha + HYT-C @ 2.0 kg/ha (T_3) in 2010, In 2011 it was *at par* with all other treatments except N_{120} P_{60} K_{40} (Rec. NPK) (T_1) and N_{60} P_{30} K_{20}+ HYT-A @ 1.0 l/ha +HYT-B @ 2.0 l/ha +HYT-C @ 2.0kg/ha(T_5), whereas in 2012 it was *at par* with N_{120} P_{60} K_{40} + HYT-A @ 1.0 l/ha (T_2), N_{120} P_{60} K_{40} + HYT-A @ 1.0 l/ha + HYT C @ 2.0 kg/ha (T_3) and N_{120} P_{60} K_{40} + HYT-A @ 1.0 l/ha +HYT-B @ 2.0 l/ha +HYT-C @ 2.0kg/ha (T_4) (Table 3).

Abedi *et al.* (2011) observed that, with increasing levels of nitrogen from 80 to 160 and 240 kg ha^{-1}, wheat grain yield significantlyincreased (52%, 115% and 95% over control in 80, 160 and240 kg N ha^{-1} treatments, respectively) compared to control and maximum wheat grain yield was obtained from30 kg ha $^{-1}$ compost application and 160 kg N ha $^{-1}$.

Another similar three years field study revealed that the wheat grain yield fluctuated, on average, from 2.23 to 4.25 t ha^{-1}at nitrogen rate 50 kgha^{-1}and with increase in nitrogen up to 100 and 150 kg ha^{-1} improved the grain yield remarkably(Jermuss and Vigovskis, 2008).

Similarly, findings of Ali *et al.* (2011) also revealed that highest value for grain yield (3.85 t ha^{-1}) was obtained for 130 kg N ha^{-1}, which was significantly different than the grainyields with applicationof 180 kg N ha^{-1}, 80 kg N ha^{-1} and control .

Partial factor productivity ofrice

Partial factor productivity(PFP) of rice reported similar trend in three years *i.e.,* 2010, 2011 and 2012 which was observed to be highest (55.50, 74.22 and 84.08, respectively) in N_{60} P_{30} K_{20}+ HYT-A @ 1.0 l/ha +HYT-B@ 2.0 l/ha +HYT-C @ 2.0kg/ ha (T_5) followed by N_{120} P_{60} K_{40} + HYT-A @ 2.0 l/ha +HYT-B@ 5.0 l/ha +HYT-C @ 5.0kg/ha (T_6). Whereas, minimum partial factor productivityin 2010 and 2011 was recorded in N_{120} P_{60} K_{40} + HYT-A @ 1.0 l/ha + HYT-C @ 2.0 kg/ha (T_3). However, in 2012 lowest partial factor productivity after N_{120} P_{60} K_{40} (T_1) was recorded inN_{120} P_{60} K_{40} + Suryamin (T_7)(Fig 1).

Similar findings was also reported by Bagayoko(2012)where partial factor productivity varied greatly from 12 to 105 kg depending on the treatment and in general the partial factor productivity declined with increasing level of N and P application. The highest value (105.5 kg grain kg^{-1} N applied) was observed with minimum P application and zero N level (N_0P_{10}) and the lowest value (12.3 kg grain kg^{-1} N applied) with the highest fertilizer rate ($N_{200}P_{30}$).

Partial factor productivity of wheat

Partial factor productivity of wheat (45.22, 59.62 and 59.13) during 2010, 2011 and 2012, respectively was highest in N_{60} P_{30} K_{20}+ HYT-A@ 1.0 l/ha +HYT-B@ 2.0 l/ha +HYT-C@ 2.0kg/ha (T_5) followed by N_{120} P_{60} K_{40} + HYT-A@ 2.0 l/ha +HYT-B@ 5.0 l/ha +HYT-C@ 5.0kg/ha (T_6). However, lowest partial factor productivity was recorded in N_{120} P_{60} K_{40} (T_1) (Fig. 2).

In an another finding, Mollah *et al.* (2009) reported that the PFP was higher in all bed planting treatments than conventional method with100kg N ha^{-1}. Bed planting with 60 kg N ha^{-1}resulted in the highest PFP (36.2 - 42.0 kg grain kg^{-1}N) and with the increase in N rate, the PFP was decreased.

From the above discussion it may be opined that application of recommended NPK with higher dose of HYT A+B+C exhibited best results in both rice and wheat in terms of root volumes, yields and yield parameters over three consecutive years of experimentation. However, the partial factor productivity of nitrogen in both rice and wheat was found higher in N_{60} P_{30} K_{20}+ HYT-A@ 1.0 l/ha +HYT-B@ 2.0 l/ha +HYT-C@ 2.0kg/ha (T_5) followed by N_{120} P_{60} K_{40} + HYT-A@ 2.0 l/ha +HYT-B@ 5.0 l/ha +HYT-C@ 5.0kg/ha (T_6). Thus, high yield technology products (HYT A, B & C) can enhance the productivity of rice and wheat under rice-wheat system which is pre-dominant and nutrient exhaustive system of Indo-Gangetic plain of India. Application of the combination of these HYT products can also reduce the NPK dosage to some extent with same level of productivity as recommended NPK.

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