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Phenology, Yield and Nutrient Uptake Efficiency of Wheat as Affected by Organic and Inorganic Nitrogen Fertilizer alone and in Combination with Effective Microorganism

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ABSTRACT

Cultivating wheat cultivars on nutrient depleted soils causes poor stand and low yield. Little attention is paid to the performance of newly developed cultivars grown on nutrient deficient soil improved with different types of compost and organic manures. Field studies were conducted to evaluate the effect of organic manures viz; Farm Yard and Poultry manure and inorganic nitrogen fertilizer alone and incombination with EM on phenology, yield and nutrient uptake efficiencies of Wheat. The experiment was conducted at farmer's field, Dargai Malakand Agency of Khyber Pakhtunkhwa-Pakistan during winter season 2011-12 and 2012-13. The experiment was laid out in Randomized Complete Block Design (RCBD) with split plot arrangement. In the main plots, presence and absence of EM was compared. In sub plots, the treatments include T_1 = control, T_2 = Urea @ 120 kg N ha^{-1}, T_3=FYM @ 8 t ha^{-1}, T_4 = PM @ 4 t ha^{-1}, T_5 = 50 % N from Urea + 25% N from FYM + 25% N from PM were studied. The results revealed that sole application of organic and inorganic N fertilizers did not improve the growth and yield attributes significantly. Results further indicates that combined application of 50 % N from Urea + 25% N from FYM + 25% N from PM along with EM @ 50 L ha^{-1} were found more effective in enhancing biological yield (13.08tha^{-1}) and grain yield (3.65t ha^{-1}). Application of EM along with FYM, PM or inorganic fertilizers enhanced nutrients/NPK uptake efficiencies in plant tissues by 19.66, 9.53 and 12.06 % as compared to control plots receiving no fertilizer/ manure.

Key words: Effective microorganisms, Organic manures, Mineral N, Integrated use, Wheat Yield

Introduction

Conventional agriculture is largely dependent on chemical fertilizers which cause problems related to environmental degradation and human health. Concern is growing that food produced under such farm management may not be safe or of good quality and has forced researchers to find alternatives to chemical fertilizer (Shaxson, 2006; Chen, 2008). Effective and widespread use of organic manures/fertilizers has great promise as a source of multiple nutrients and ability to improve soil characteristics (Moller, 2009). It can substantially reduce chemical fertilizer use without detrimental effects on crop yields (Aryal *et al.*, 2003). One such effort was made by Higa (1989), who isolated some beneficial microorganisms from the soil and called them Effective Microorganisms. EM contains selected species of microorganisms including predominant populations of lactic acid bacteria, yeasts, smaller numbers of photosynthetic bacteria, actinomycetes, fermentative fungi and other types of organisms. All of these are mutually compatible with one another and can coexist in liquid culture. EM may enhance the fermentation of organic materials and efficacy as a fertilizer. EM-bio-fertilizer improved soil properties such as organic matter content and total

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NPK in soil. Research has shown that the inoculation of EM cultures to soil-plant ecosystem improve soil health, growth and yield of crops. Tahir *et al*., 2002 reported that EM application significantly improve the soil and crop growth and yield. This type of farming provides several benefits to the growers and it is an environmental friendly method of cultivation (Javaid, 2011). EM produces greater quantities of better quality crops and enhances crop yields in organic systems in most environments (Javaid, 2006). Alam and Shahl, (2003) stated that in some cases application of organic manures alone was found useful but integrated use of organic manure and chemical fertilizer has proved more rewarding (Khanam *et al.* 2001, Alam *et al.,* 2005). The alkaline and calcareous soils of Pakistan are extensively deficient in nitrogen, phosphorus, zinc and organic matter, hence application of in-organic fertilizer is considered imperative for increasing crop production (Haji *et al*., 2014). The efficiency of mineral fertilizers with organic manures can meet part of the nutrient needs of crops and results an increase in crop production and improve soil quality (Khalil *et al.,* 2002). The organic and other bio-sources of plant nutrients not only supply necessary nutrients but by interaction with chemical fertilizers they also increase their efficiency and thereby reduce environmental hazards (Javaid, 2010). Keeping these aspects in view the present study was designed to achieve the following objectives:

1. To quantify the comparative performance of organic and inorganic manures on phenology, growth and yield of wheat under semiarid tropical climate of Khyber Pakhtunkhewa.
2. To find out the best combination of different amendments as well as EM inoculum for enhancing agronomic and uptake efficiency in wheat crop.

Materials and Methods

Experimental site and background

A two years field experiment was conducted to study the effect of integrated use of organic and inorganic fertilizers with or without effective microorganisms (EM) at farmer's field, Dargai Malakand Agency of Khyber Pakhtunkhwa-Pakistan during winter season 2011-12 and 2012-13. The surface soil (0-30 cm) of the experimental site had pH 8.3, ECe 2.31 dS m^{-1}, organic matter 0.71 %, total N 0.60 g kg^{-1}, available P 5.3 mg kg^{-1} and K 75.2 mg kg^{-1}. The soil was sandy clay loam and classified as Typic Dystrudepts belonging to Pirsabak soil series (Soil Survey Staff, 2007). The experimental field is located at 32°N latitude, 72°E longitude and an altitude of 477 m above sea level. The climate of the experimental site is classified as semiarid tropical with average rainfall of 155 mm, with more than 70% of it occurring from July to the end of September. Mean temperature is lowest (3°C) in January and highest (41°C) in July (Fig.1).

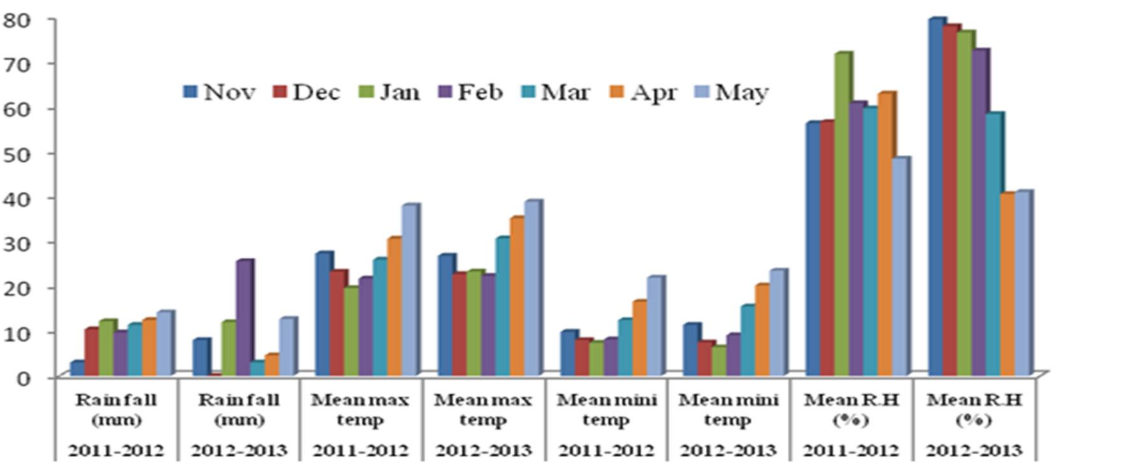

Fig. 1: Monthly maximum, minimum temperature (°C), relative humidity (%) and rain fall (mm) during growing season 2011-12 and 2012-13.

Experimental design and data collection

The experiment was laid out using RCB design with Split Plot arrangements replicated four times where EM was kept in main plots and FYM, PM along with Urea were kept in sub plots. A sub-plot size was 7.5 m^2 (1.5 m x 5 m) having 5 rows of 30 cm apart and plant to plant 6 cm was used. Wheat cultivar Uqab-2000 was used as test variety. The crop was sown on November 15th 2011-12 and were grown at the same field during next season with hand drill using seed rate of 120 kg ha^{-1}. Nutrient analysis of FYM and PM manure was performed according to standard procedure of IITA (1990). NPK dose were adjusted including quantity of N, P and K coming from FYM and poultry manure before application. The required quantity of FYM and PM were added to each plot one month before and thoroughly mixed with the soil for full decomposition. A recommended dose of P_2O_5 and K_2O at @ 90 and 60 Kgha^{-1} were applied at the time of sowing while nitrogen as Urea was applied in two equal splits at sowing and tillering stage. The EM (1:1:20, EM: Molasses: water) was applied @ 50 L ha^{-1} in five irrigations. Five treatments viz., (T_1 = control) (T_2 = Urea @ 120 kg N ha^{-1}) (T_3=FYM @ 8 t ha^{-1} alone) (T_4 = PM @ 4 t ha^{-1} alone) (T_5 = 50 % N from Urea + 25% N from FYM + 25% N from PM) were used. After proper germination and establishment, cultural practices and plant protection measures were performed according to the recommended practices. Irrigations were given to crop at one month interval. Pre and post-emergence herbicide were applied to control weeds. The crop was harvested at maturity during 1st week of May each year. Standard procedures were followed to collect data for growth and yield parameters of wheat. For plant height 10 plants were selected randomly from each plot at maturity and plant height was measured from base of the tiller to tip of spike with a meter stick and average plant height was computed. Ten spikes were selected at random from each plot and spikes length, spikelet per spike and number of grains per spike was recorded and average was calculated. Similarly, 1000-grains of every plot were counted by seed counter (Seed Buro, Model Number 801-10) and weighed with an electric balance. The crop was sun dried for few days and harvested on maturity. These samples were threshed manually to record grain yield. Biological yield of sun-dried samples in kilogram (kg) was recorded for each plot and reported in t ha^{-1}.

Plant Tissues Analysis

Plant samples were harvested at maturity randomly from each plot. All samples were dried in oven at 70˚C till a constant weight was attained. Dried plant samples were milled and ground for tissue analysis. Total N was analyzed using micro-kjeldahl procedure according to methods of AOAC (2008). Total P were determined by the Vanadomolybdate method, K by flame photometry.

Nutrient uptake efficiency (NUpE) was estimated as:

$$\text{NUp E (\%)} = (\text{Nutrient taken-up by the plant/Nutrient applied})*100$$

Statistical analysis:

Statistical analysis of 2 year average data was carried out using MSTATC statistical computer software. When significant F values were obtained then applying Least Significant Difference (LSD) test at 5% probability, compared the treatment means (Steel *et al*., 1997).

Results and Discussion

Phenological Parameters

Application of organic and inorganic fertilizer alone and in combination with EM showed a significant difference amongst the treatments for phenological parameters. Minimum days (108) to spike initiation were recorded in plots where EM was applied, whereas maximum days (110) to spike initiation were recorded in control plots (Table 1). Similar results have been recorded by Muthaura *et al*., (2010) who reported that growth and yield of pigweeds may be improved by inoculating the plants with effective microorganisms and as a result reduce the use of fertilizers in production of this vegetable hence promoting sustainable agriculture. The longest duration to spike initiation (116 days) was noted in the treatment where no organic and inorganic fertilizer was applied whereas minimum days (107 days) to spike initiation were taken by the treatment T_5 where 50 % N from Urea + 25% N from FYM + 25% N from PM were applied. Maximum plant height of 104.03 (cm) was observed in EM treated plots as compared to control treatment. Comparing relevant treatment with and without EM, it was observed that supplementation of EM with manure/fertilizer source increased plant height. A maximum increase of 3.7% was observed in plant height over control treatment. The increase in plant height may be due to availability of nutrients especially N might have increased the cell division and elongation phenomena and thus taller plants were produced (Iqtidar *et al.,* 2006). Spike length (cm) was significantly affected by organic and inorganic N sources along with EM of wheat. Significantly longer Spikes (13.93 cm) were found in E1 as compared to Eo (12.70 cm). Comparing relevant treatment with and without EM, it was observed that maximum spike length (2.69% more than control) was observed in T_5 where 50 % N from Urea + 25% N from FYM + 25% N from PM were applied (Zeidan and Kramany, 2001). All other treatments receiving FYM, PM and Urea were statistically at par compared to each other. Tillers plant^{-1} demonstrate similar trend of increase both in main and as well as in sub plots.

Table 1: Effect of organic and inorganic N sources alone and in-combination with EM on phonological parameters of wheat.

Treatments	Days to spikes initiation	Plant height (cm)	Spike length (cm)	Tillers Plant^{-1}	Days to maturity
EM (Main plot					
E0 (Without EM)	110 a	99.21 b	12.70 b	4.22 b	152 a
E1 (With EM)	108 b	104.03 a	13.93 a	4.22 b	148 b
LSD	0.97	2.78	0.83	1.85	0.48
Organic & in-organic N Sources (Sub plot)					
T1	116 c	83.50 d	11.34 c	4.23 c	150 c
T2	114 b	93.42 b	13.37 b	5.10 b	147 b
T3	114 b	87.23 c	13.50 b	5.33 b	146 b
T4	113 b	89.50 c	13.93 b	5.77 b	145 b
T5	107 a	102.20 a	14.03 a	6.54a	140 a
LSD (0.05)	1.13	3.47	0.89	1.26	0.49
Interaction	NS	NS	NS	NS	NS

**Means of the same category followed by different letters are significantly different at 0.05 level of probability using LSD test.*

Haji *et al.,* (2014) who concluded that the combination of organic and inorganic fertilizers could increase plant growth, yield, quality and soil fertility when combined with EM at & of 10 L ha^{-1}. Javaid and Bajwa, (2011) stated that the promoted wheat growth could probably be attributed to activity of photosynthetic bacteria such as Rhodopseudomonas palustris and Rhodobacter sphaeroides in EM solution, which are a group of independent, self-supporting microbes. These bacteria could synthesize useful substances from secretions of plant roots, or soil organic materials. Minimum days (148) to maturity were recorded in plots where EM was applied, whereas maximum days (152) to maturity were recorded in control plots (Table 1). The longest duration to maturity (150 days) was noted in the treatment where no organic and inorganic fertilizer was applied whereas minimum duration (140 days) to maturity were observed by the treatment T_5 where 50 % N from Urea + 25% N from FYM + 25% N from PM were applied. Kim *et al*., 2004 reported that EM solution produced such microbes which include amino acids, nucleic acids, sugars, polysaccharides and bioactive substances, all of which accelerate crop growth cycle.

Yield and yield components

Data regarding organic and inorganic fertilizers N sources with and without EM showed significant effect on the yield parameters of wheat (Table 2). Number of tillers (m^{-2}) was significantly influenced by the application of EM. The highest number of tillers (342.29 m^{-2}) was recorded in EM treated plots over those without EM plots (305.67 m^{-2}).Integrated nutrient management also significantly influenced number of tillers (m^{-2}). Maximum number of (338) tillers (m^{-2}) was observed in T_5 where 50 % N from Urea + 25% N from FYM + 25% N from PM were applied. The minimum number of (209) tillers (m^{-2}) were recorded in control plots (T_0). These results are in accordance with the findings of Dixit and Gupta (2000) who reported that using different organic materials alone and in-combination with mineral fertilizers has positively affected the number of tillers (m^{-2}) in rice crop which finally contributed towards increase in paddy yield. Similar trend of increase in number of tillers m^{-2} was observed when different organic / inorganic fertilizers along with EM were applied to wheat crop. Number of grains spike^{-1} showed significant variation between organic and inorganic fertilizer in-combination with EM. Maximum number of grains spike^{-1} (55) was produced from EM treated plot while minimum number of grains spike^{-1} (43) was observed in control plots where no EM was applied. The treatments of integrated nutrient management also significantly increased the number of grains spike^{-1}. The maximum number of grains spike^{-1}(60) was recorded in T_5 where 50 % N from Urea + 25% N from FYM + 25% N from PM were applied. The interaction between EM and integrated organic and inorganic nutrient management was found statistically highly significant (*$P < 0.01$*). Similar results have been found by Zhang *et al*. (2006) who reported that yield attributes i.e tiller numbers, grain number and 1000 grain weight increased with the addition of P which ultimately improved the productivity of wheat. Biological yield of wheat was significantly affected by organic and inorganic fertilizer N sources in-combination with EM. Significantly more biological yield was obtained from EM treated plot (12.11t ha^{-1}) as compared to control plots which was recorded (11.30 t ha^{-1}). These results are in line with the findings of Moller (2009) who observed an increase in biological yield of sorghum, maize and rice respectively. The treatments of integrated nutrient management significantly affected the biological yield of wheat. Maximum biological yield (12.53 t ha^{-1}) was produced in T_5 plots. Minimum biomass (8.61 t ha^{-1}) was yielded in control (T0) where no organic, inorganic and EM was applied. The interaction between EM and integrated management of organic and inorganic N sources was found statistically non-significant.

Table 2: Effect of organic and inorganic N Sources alone and in-combination with EM on yield and yield components of wheat.

Treatments	Tillers (m^{-2})	No. of grains spike $^{-1}$	Biological yield (t ha^{-1})	Grain yield (t ha^{-1})	1000-grain weight (g)
EM (Main plot					
E0 (Without EM)	305.67 b	43 b	11.30 b	2.25 b	37.03
E1 (With EM)	342.29 a	55 a	12.11 a	3.11 a	39.21
LSD	30.7	2.96	0.45	0.18	NS
Organic & in-organic N Sources (Sub plot)					
T1	209 d	50 c	8.61 d	2.12 d	38.01
T2	295 c	54 b	10.30 b	3.31 b	40.21
T3	318 b	55 b	10.55 b	2.95 c	41.35
T4	321b	56 b	11.38 b	3.09 c	41.53
T5	338 a	60 a	12.53 a	3.65a	42.15
LSD (0.05)	9.65	2.96	1.03	0.29	NS
Interaction	**	NS	NS	NS	NS

**Means of the same category followed by different letters are significantly different at 0.05 level of probability using LSD test.*

Our findings are in agreement with those of Swarup and Yaduvanshi (2000) who reported that different yield parameters including total biomass significantly increased with appropriate combination of organic and inorganic fertilizers. Grain yield was significantly increased by application of different treatments. Different organic and inorganic fertilizer N sources in conjunction with EM resulted in more grain yield (3.11t ha^{-1}) than the control plots (2.25 t ha^{-1}). Saad and Hammad (2005) reported similar results by the application of calcium superphosphate along with bacterial inoculation for improvement in grain yield of wheat. Among the integrated nutrient management treatments, T_5 (50 % N from Urea + 25% N from FYM + 25% N from PM) had significantly increased grain yield and produced (3.65t ha^{-1}) over control (2.12 t ha^{-1}). The interaction between EM and different N sources was found statistically non-significant. These results are in concurrence with Aziz *et al*., (2006) who stated that agriculture productivity could be increased by efficient management of macro and micro-nutrients because it is deficient in most of our soils due to its reaction with calcium to form insoluble compounds. Gill *et al*. (2004) also observed similar findings and stated that Pakistani soils, being calcareous, are generally deficient in P and this deficiency of phosphorus can reduce the yield of crops up to 10 -15%. The increase in yield by FYM, PM and Mineral N in combination with EM is attributed to the increase in number of tillers m^{-2}, grains $spike^{-1}$ and biological yield. The findings of Zaka *et al*., (2003) were also in the same direction that organic and inorganic fertilizers which significantly affected growth parameters and yield attributes that ultimately enhanced wheat yield. Robin *et al.,* (2009) concluded that the combination of organic and inorganic fertilizers along with proper amount of EM inoculum could increase plant growth and yield of wheat through enhanced nutrient (macro & micro) use efficiency in the presence of EM.1000 grain weight was non-significantly influenced by the application of EM along with organic and inorganic fertilizer N sources, however, heavier grains were observed in EM treated plots as compared to control plots.

Nutrient uptake Efficiency

Significant variations were observed on the effect of organic and inorganic N sources in the presence or absence of EM on N, P and K uptake efficiency by wheat crop (Table 3). The highest uptake efficiency percentage of 34.03, 9.21 and 17.35 of N, P and K were recorded in the plots receiving EM over the control plots. While, the effect of FYM and PM manures showed that the highest values of N, P and K uptake efficiency over mineral N fertilizer. Maximum NPK uptake was observed in T_5 where 50 % N from Urea + 25% N from FYM + 25% N from PM were applied. The lowest NPK uptake was obtained from control plots where no organic and inorganic fertilizer was applied. The highest uptake of N, P and K from T_5 integrated nutrient management plot might be due to the increase in NPK solubility/availability as a result of organic acids produced during organic matter decomposition. Similar results were reported by Satyajit *et al*., (2003) who reported that the application of phosphorus fertilizers increased the concentration and uptake of nutrients of N, P, K and S in straw and grain of chickpea and the results also indicated that addition of FYM gave the highest concentration and uptake of these major nutrients. Haji *et al*., (2014) reported that FYM and PM treated with EM made their nutrients available for crop use as needed unlike inorganic fertilizer which releases it constituents rapidly beyond the need of crop. Similar effects of EM application on wheat, rice, cotton, mungbean, cowpea, and capsicum N, P, K nutrition in soil organic amendment system have been reported by Khaliq *et al.,* (2006) and Javaid and Bajwa (2011). Khaliq *et al*., (2006) reported that application of organic materials or EM alone did not increase yield significantly over control in cotton crop. However, combination of both resulted in a 44% increase in yield over control. They further stated that application of EM with mineral NPK resulted in a 14% increase in cotton yield over mineral NPK alone.

Table 3: Effect of sole organic and inorganic N sources and application with EM on uptake of N, P and K (Kg ha^{-1}) in Wheat.

Treatments	N Uptake	P Uptake	K Uptake
EM (Main plot)			
E0 (Without EM)	29.21 b	7.25 b	13.03 b
E1 (With EM)	34.03 a	9.21 a	17.35 a
LSD	1.54	0.89	0.59
Organic & in-organic N Sources (Sub plot)			
T1	22.59 e	4.12 e	11.09 d
T2	28.02 d	6.31 d	13.21 d
T3	34.56 c	8.95 c	17.35 c
T4	38.34 b	11.09 b	20.53 b
T5	42.25 a	13.65a	23.15 a
LSD (0.05)	3.16	1.34	2.22

**Means of the same category followed by different letters are significantly different at 0.05 level of probability using LSD test*

Conclusions

The results of the present investigations, lead us to the conclusion that there is a significant effect of integrated nutrient management of FYM, PM and mineral fertilizer, when applied in combination with EM on phenology, yield components and uptake in wheat. EM showed better results to solubilize higher amounts of nutrients and would be more beneficial in soils low in organic matter.

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