Research Article

Phenology, Crop Stand and Biomass of Wheat in Response to Farmyard Manure and Soil Amendments

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Abstract | The stimulated decomposition of farmyard manure (FYM) through soil amendments is considered to improve the nitrogen (N) availability and hence the crop biomass. With this view, the four soil amendments [i.e. No-amendments, Min-N (30 kg N ha^{-1}), humic acid (2.5 kg ha^{-1}) and effective microbes (200 L Mg^{-1} of FYM)] were added to five levels of FYM (i.e. 0, 5, 10, 15 and 20 Mg ha^{-1}) and their impact were quantified in terms of wheat phenology, crop stand and biomass during two years studies (2016-17 and 2017-18). Min-N was provided from urea, humic acid from "humic plus" a commercial product having 40% humic acid, and effective microbes from "bioaab" a commercial product having beneficial microbes like bacteria, yeast and actinomycetes. Average over years, the maximum days to anthesis (126 days), physiological maturity (154 days) and enhanced emergence (9 days) were observed with 20 Mg FYM ha^{-1}. The emergence m^{-2} (126), leaf area tiller^{-1} (107 cm^2), plant height (96.5 cm) and biomass (11783 kg ha^{-1}) were improved with 20 Mg FYM but were non-significantly different from plots having 15 Mg FYM ha^{-1} over two years averaged data. Among the amendments, greater days to anthesis (126 days) and physiological maturity (154 days) was noted with effective microbes over two years. Similarly, the addition of effective microbes has increased the emergence m^{-2} (123), leaf area tiller^{-1} (105.6 cm^2), plant height (96.6 cm) and biomass (11386 kg ha^{-1}). The physiological maturity delayed when FYM increased from 0 to 20 Mg ha^{-1} and applied with effective microbes. However, using $\geq$10 Mg FYM ha^{-1} has no differences in emergence m^{-2} across the amendments. In conclusion, the addition of effective microbes can enhance crop stand and biomass when added with 15-20 Mg FYM ha^{-1}.

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Introduction

Wheat (*Triticum aestivum* L.) belonging to family Poaceae and utilized for food and feed purpose. Pakistan occupies 8th position in wheat production (Muhammad *et al*., 2013). It is cultivated over 42% of total cultivable land in Pakistan with average production of 2919 kg ha^{-1} (MNFSR, 2018). The average yield of wheat in Pakistan is not satisfactory for the food demands of increasing population. Pakistani nation prefer wheat over the grains crops like rice, maize, barley etc. (Muhammad *et al*., 2013). This low wheat productivity is being associated with low soil fertility and imbalance use of nutrients.

Frequent and continuous supply of nutrients results in improving the yield and yield parameters (Muhammad *et al*., 2013). Wheat needs huge amount of nutrients including nitrogen, and thus depleting

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soil fertility (Sainju *et al*., 2002). Due to lower N status and soil organic matter (SOM) contents of our province (Sharif *et al*., 2002), the farmers need chemical fertilizer for optimum and economic yield (Ahmad, 1999). The mineral N fertilizer can supply the required nutrients for the plants, however, it can cause environmental pollution (Mukherjee and Zimmerman, 2013). Thus, the low soil fertility problem can be eliminated by using the organic sources of nitrogen (Ibrahim *et al*., 2020). The organic fertilizers included manure of farm, sheep, poultry, and different commercial based derived compost. Among them, farmyard manure is a major source of nitrogen and enhance the soil fertility (Khan *et al*., 2019a) However, it is used in huge amount and decomposed slowly for the current crop (Muhammad *et al*., 2018).

The addition of fertilizer (Khan *et al*., 2019b), humic acid (Akhtar *et al*., 2014), and effective microbes (Liu *et al*., 2010) are considered to enhance crop production via stimulating microbial activity. The addition of N induced changes in soil microbial community and accelerate the biochar degradation (Schulz and Glaser, 2012). Nitrogen has a positive effect on easily degradable organic material (Sharif *et al*., 2002). The humic acid is a natural product and contains 51-57% organic carbon, 4-6% nitrogen, 0.2-1% P (Sharif *et al*., 2002). The greater C amount available in HA act as a food for soil microbes. The increased microbial activities decompose the manure and results in more nutrients availability and thus improve the plant growth through chelating and making available the unavailable nutrients for plants (Tahir *et al*., 2011). The effective microbes addition to the soil increased the decomposition of SOM (Singh *et al*., 2011). It is a bio-fertilizer, which increased the decomposition through stimulating microbial activities and thus had increased the crop grain yield and biomass (Khan *et al*., 2014). This practice is considered is eco-friendly and economical, when compared to synthetic fertilization (Singh *et al*., 2011). It can reduce the use of chemical fertilizer and improved the soil biota. The effective microbes efficiently decompose animal manures into available nutrients and thus increase the efficiency of organic sources of nutrients (Akhtar *et al*., 2014).

The enhanced microbial activity increased manure decomposition (Schulz and Glaser, 2012), which is important for the current production system in the province. However, information is limited on this important research question. Manure had increased the soil fertility and crop production. However, the slow releasing nutrients from the decomposing FYM is considered a strong obstruct in this regard. Therefore, effect of organic and inorganic amendments for improving the manure decomposition and its effects on wheat biomass and crop stand were undertaken in field studies. The objectives of the designed experiments were a) to find out the optimum level of farmyard manure for improving wheat biomass and stand establishment, b) to find out the suitable amendment for improving FYM decomposition, and its effects on wheat crop stand and biomass and c) to understand the interactive response of FYM levels and amendment for improving wheat biomass and stand establishment.

Materials and Methods

Site description

The impact of adding amendments on farmyard manure (FYM) decomposition and its effect on wheat biomass and stand establishment were carried out in field experiments. The experiments were conducted at Agricultural Research Farm, the University Agriculture Peshawar (34°N, 71°E), north-west Pakistan for two consecutive years 2016-17 and 2017-18. The initial physico-chemical properties (before sowing) of randomly taken soil samples (20 cm depth) from five different locations are given in Table 1. The soil was alkaline having pH (8.4), SOC (0.51%), total N (0.05%), mineral N (18.24 mg kg^{-1}), extractable P (2.7 mg kg^{-1}), K (87.4 mg kg^{-1}) and soil bulk density (1.24 g cm^{-3}). The soil of the experimental site was silt loam with sand (29.1%), silt (55.7%) and clay (15.2%), piedmont alluvium and classified as Ustochrepth based on USDA classification (Anonymous, 2007). The cropping sequence in the study site was wheat-maize-wheat rotation, with inclusion of legume crop occasionally in the last 10 years. The temperature and rainfall data of the study area is presented in Figure 1. The minimum temperatures ranged from 2.8 °C (January, 2018) to 22.9 °C (May, 2017) with averaged temperature of 13.5 °C, whereas maximum temperature ranged from 16.8 °C (December, 2016) to 38.4 °C (May, 2017) with averaged temperature of 28.6 °C. The rainfall occurred across the growth period in both years, except in November, December 2016, as well as in January 2017. Similarly, in March in both years, the rainfall was lesser than crop water requirements. Therefore, the crop water requirements were met from external irrigations, when needed. A total of six irrigations were applied to the wheat crop at crown root initiation, tillering, jointing/boot, anthesis, milk and grain formation stages using flood irrigation during both years.

Table 1: *The physico-chemical properties of soil and amendments used in the experiment.*

Properties	Units	Soil	FYM	Humic acid
Organic carbon	%	0.51	15.7	55.43
Total N	%	0.05	1.15	4.75
Mineral N	mg kg^{-1}	18.24	-	-
Extractable P	mg kg^{-1}	2.70	-	0.72
Extractable K	mg k^{g}-1	87.41	-	-
pH		8.04	8.70	-
Electrical conductivity	dS m^{-1}	1.69		-
Moisture holding capacity	%	34.21	51.11	-
Bulk density	g cm^{-3}	1.24	-	-
Textural class		Silt loam	-	-
Sand	%	29.10	-	-
Silt	%	55.69	-	-
Clay	%	15.21	-	-

FYM: *Farmyard manure.*

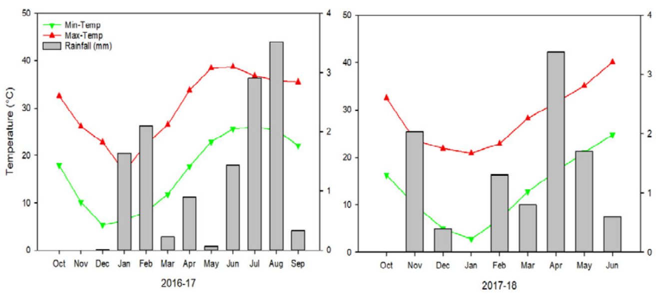

Figure 1: *Climatic data (rainfall and temperature) of the experimental site during 2016-18.*

Materials and treatments

Five levels of FYM (i.e. 0, 5, 10, 15, and 20 Mg ha^{-1}) were mixed with four amendments [i.e. control (no amendment), Min-N (mineral nitrogen @30 kg N ha^{-1} as urea N), HA (humic acid @ 2.5 kg ha^{-1}) and EM (effective microbes @ 200 L Mg^{-1} of FYM). The FYM was collected from the dairy Farm, the University of Agriculture, Peshawar before the initiation of the experiments and analyzed for physico-chemical properties (SOC, pH, total N) with the detail given in Table 1. Min-N amendment was supplied from synthetic fertilizer i.e. urea (46% N), humic acid from "humic plus" having 40% humic acid and 7% K_2O available as commercial product of Al-Hameed Chemicals Pvt limited. The effective microbes were supplied from "Bioaab" a commercial product of NFRDF NGO prepared with collaboration with the Faculty of Agriculture, The University of Faisalabad-Pakistan. The bioaab contained *Rhodopseudomona* ssp., *Lactobacillus* sp., *Saccharomyces* sp. *and Actinomycetes* etc. and molasses as media. The effective microbe solution was prepared by using 2% of commercial product "bioaab" and 98% distilled water. The different organic amendments (humic acid and bioaab i.e. effective microorganisms) and inorganic amendment (mineral nitrogen in the form of urea) was mixed with FYM according to the given rates, and thereafter was applied to the respective plots. However, in case of no-amendments, an equivalent amount of water was added to the FYM to nullify the effect of added water on FYM decomposition.

Experimentations

The experiments were laid out in RCB design with four replications. The field was ploughed 2-3 times using common cultivator at proper field capacity level. The treatments were allotted to the respective plots after field layout, 25-30 days before sowing and were irrigated if needed for maintaining field capacity till sowing of crop. The plots size was 3×5 m, having 10 rows 30 cm apart and 5 m long. 25-30 days after treatments imposition, the field was ploughed using rotavtor for seed bed preparation. Spring wheat (cv. Pirsabak-2013) was sown on 21st November in 2016 for first wheat crop and 11th November in 2017 for 2nd wheat crop at the seed rate of 120 kg ha^{-1}. In addition to the N fertilizers, basal doses of P and K were applied to the soil @ 60 kg ha^{-1} at time of sowing. Weeding, hoeing and irrigation (a total of six, mentioned above) were carried out uniformly for all plots.

Observations and measurements

Random soil samples (20 cm depth) were made from five locations from the whole experimental plot and composited before wheat plantation. The composite samples were brought to laboratory. Fresh soil samples (manually removed stones and debris) were used for mineral N determination. Whereas the remaining parts of the samples were air dried and grinded with grinder (Kinematic, Switzerland) of 2 mm mesh size, and was store for N, C, pH and EC determinations. The mineral N determination was carried out according to Keeney and Nelson (1982). Soil total N was measured by the procedure of Bremner and Mulvaney (1982) following Kjeldahl principle, and Organic C by the modified method of Nelson and

Sommers (1982). The soil pH was recorded using the Mclean (1982) method of 1:5 (soil: water) suspension, whereas the soil bulk density was measured with Black and Hartge (1984) procedure.

Seedling emergence was observed daily from date of sowing till completion of 80% seedling emergence in each plot. Days to emergence data was recorded as the difference between sowing date and the date when 80% emergence occurred in each plot. Seedlings were counted in three locations at random across one-meter length in central three rows when 80% of plants emerged, and emergence m^{-2} were thus derived using the formula:

$$\text{Emergence } m^{-2} = \frac{\text{Seedling counted}}{\text{Row} - \text{Row} \times \text{No. of rows} \times \text{row length}} \times 1$$

Days to anthesis and physiological maturity were counted from sowing date till completion of 80% anthesis and maturity in each plot, respectively. The yellowing of leaves and spike was considered criteria for determination of physiological maturity in wheat. The height of five plants at random from base to tip excluding awns were taken with measuring rod, averaged and taken plant height of wheat. At harvest maturity, the central six rows were harvested in each plot, and sun dried for a week in the field to determine the biomass. The dried material was weighed and expressed in kg ha^{-1} using the formula, after correcting the moisture contents.

$$\text{Biomass (kg ha}^{-1}) = \frac{\text{Biomass of six rows}}{\text{Row} - \text{Row} \times \text{No. of rows} \times \text{row length}} \times 10{,}000$$

Statistical analysis

The collected data were analyzed statistically as per the procedure of the RCB design over years. Means were separated using least significant difference (LSD) test upon significant F-test with a probability values of 5% (Jan *et al*., 2009).

Results and Discussion

Phenological observations

Days to emergence of wheat averaged over years were significantly ($p \leq 0.05$) varied with FYM application and non-significantly affected by soil amendments and years (Table 2). However, during the first year (2016-17), no differences in days to emergence were noted among FYM, amendments or its interaction. Averaged over years data shows that minimum days to emergence were recorded with 15 and 20 Mg FYM ha^{-1} (9 days) application while no difference was measured with other levels. However, with amendments application, no difference was recorded with No-amendments, Min-N and humic acid while the days to emergence was non-significantly ($p \leq 0.05$) less with effective microbes (9 days). Anthesis of wheat varied significantly ($p \leq 0.05$) with FYM application and soil amendments both in individual years as well as averaged over years (Table 2). The days to anthesis of wheat delayed by one day in the 2nd year as compared to first year (Table 2). The 20 Mg FYM ha^{-1} had delayed the wheat anthesis by 2 days over the No FYM addition over both years. A single day delay in anthesis was observed with Min-N, humic acid and effective microbes as compared to No-amendments (124 days) across the years. Physiological maturity was delayed by 2 days in year-II as compared to year-I (Table 2). The wheat physiological maturity delayed from 151 to 153 days with increasing FYM from 0 to 20 Mg ha^{-1} averaged over two years data (Table 2). Similarly, with amendments application (Table 2), maximum days to physiological maturity was taken with Min-N application (153 days) over No-amendments (151 days) over two years data. The interaction of FYM with soil amendments (Figure 2) shows that increasing the FYM from 0 to 20 Mg ha^{-1}, the physiological maturity delayed with No-amendments and effective microbes. However, with humic acid or Min-N as soil amendments, the physiological maturity did not change with increasing FYM levels from 0 to 20 Mg ha^{-1}.

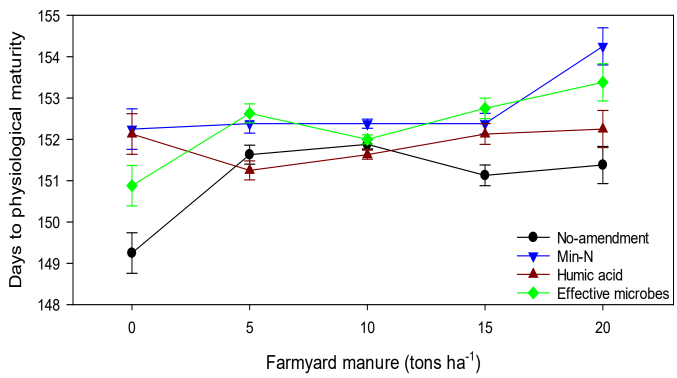

Figure 2: *Days to physiological maturity of wheat in response to FYM × Amendments interaction over years. The vertical bars are standard error of means (n = 4).*

Crop growth and stand

The leaf area tiller^{-1} was significantly ($P \leq 0.05$) affected by FYM and amendments application both in individual years as well as averaged over two years data (Table 3). However, all the interactions was found not significant. The leaf area tiller^{-1} was significantly higher in the 2nd year (100.8 cm^2) as compared to first year (97.4 cm^2). Data of two years average for leaf area tiller^{-1} (Table 3) shows that FYM addition significantly ($p \leq 0.05$) improved leaf area tiller^{-1}. Increasing FYM level from 0 to 15 Mg ha^{-1} had increased the leaf area from 89.9 to 103.5 cm^2 showing 15% increases. However, the latter was not significantly ($p \leq 0.05$) different from leaf area tiller^{-1} noted with 20 Mg FYM ha^{-1} (105.9 cm^2). Among the amendments, leaf area tiller^{-1} was maximum with effective microbes (102.9 cm^2 tiller^{-1}) as compared to No-amendments (93.5 cm^2 tiller^{-1}). Data regarding plant height (Table 3), showed significant differences ($p \leq 0.05$) for the plant height due to FYM addition both in individual years as well as averaged over two years data. The plant height was maximum with 20 Mg FYM ha^{-1} (96.5 cm) and minimum with 0-ton FYM ha^{-1} (91.0 cm) averaged over two years data. However, the plants height was non-significantly affected by amendments in first year (2016-17) but varied significantly ($P \leq 0.05$) in the 2nd year (2017-18) and averaged over two years data. With amendments addition maximum plant height was recorded with effective microbes and Min-N (95.4 and 94.9 cm, respectively) followed by humic acid (94.0 cm) and minimum plant height was recorded with No-amendments (92.8 cm) over two years data.

The application of FYM had significantly ($P \leq 0.05$) affected emergence m^{-2} both in individual year as well as averaged over two years data. However, the amendments application had not significantly ($P \leq 0.05$) affected the emergence m^{-2} in year-1 (2016-17), but had significant ($P \leq 0.05$) effects on emergence m^{-2} of wheat in 2nd years as well was averaged over two years data (Table 3). No statistical differences for wheat emergence m^{-2} was noted between years 1 and year 2 (Table 3). A total of 11% increases in emergence m^{-2} were documented with increasing the FYM from 0 to 20 Mg ha^{-1} based on two years data (Table 3). With amendments addition, no significant ($p \leq 0.05$) difference in emergence m^{-2} was noted with Min-N (119), humic acid (120) and effective microbes (121) as compared to No-amendments (114). The FYM x amendments interaction (Figure 3) shows that emergence m^{-2} sharply increased with No-amendments as compared to Min-N with increasing FYM from 0 to 10 Mg ha^{-1}. Using 10 Mg FYM ha^{-1} or above, no differences in emergence m^{-2} was noted among the amendments like No-amendments, Min-N or humic acid, however, the emergence was higher with effective microbes across the FYM levels.

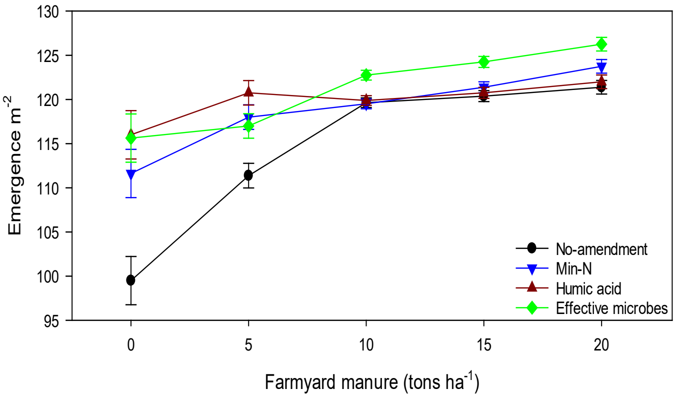

Figure 3: *Emergence m^{-2} of wheat in response to FYM × Amendments interaction over years. The vertical bars are standard error of means (n = 4).*

Crop biomass (kg ha^{-1})

Biomass of wheat was significantly ($p \leq 0.05$) higher in the following year (10620 kg ha^{-1}) than the first year (10014 kg ha^{-1}) as shown in Table 4. During 2016-17, FYM application significantly ($p \leq 0.05$) improved the biomass with all levels. Maximum biomass was observed with 15 and 20 Mg FYM ha^{-1} (10484 and 10453 kg ha^{-1}, respectively) than No FYM ha^{-1} (9204 kg ha^{-1}). With amendments addition, no significant ($p \leq 0.05$) difference in biomass was found among the amendments like No-amendments (9750 kg ha^{-1}), Min-N (9781 kg ha^{-1}) and humic acid (10027 kg ha^{-1}) but were significantly lower than effective microbes (10561 kg ha^{-1}) were non-significant. In 2017-18, wheat biomass ranged from 9523 (No FYM) to 11783 kg ha^{-1} (20 Mg ha^{-1}). With amendments addition maximum biomass produced with application of effective microbes (11386 kg ha^{-1}) over No-amendments (9838 kg ha^{-1}). Two years average data shows that biomass increased by 19% with 20 Mg FYM ha^{-1} than No- FYM. However, the biomass produced in plots having either 15 or 20 Mg FYM ha^{-1} were non-significant and produced 10888 and 11118 kg biomass ha^{-1}, respectively. Maximum biomass was produced with addition of effective microbes (10973 kg ha^{-1}) than No-amendments (9794 kg ha^{-1}) across the two years averaged data.

Phenological observations

The seedling emergence depends on the internal stored food in the cotyledon (Saharan *et al.*, 2016), optimum temperature (Zavattaro *et al.*, 2017) and moisture availability (Saikia *et al.*, 2015). The plant took less days to emergence in plots where 15 and 20 Mg

Table 2: *Phenological observations (days) of wheat as affected by farmyard manure addition modulated by various amendments during 2016-17 (Year I) and 2017-18 (Year II).*

Treatments	Phenological observations (days)								
	Emergence			Anthesis			Maturity		
Farmyard manure (FYM, Mg ha^{-1})	Year I	Year II	Mean	Year I	Year II	Mean	Year I	Year II	Mean
0	10 a	10 a	10 a	123 d	124 c	124 c	151 b	152 c	151 c
5	10 a	10 a	10 a	124 c	124 c	124 c	151 b	153 b	152 b
10	10 a	9 b	10 a	124 c	125 b	125 b	151 b	153 b	152 b
15	10 a	9 b	9 b	125 b	126 a	125 b	152 a	153 b	152 b
20	9 a	9 b	9 b	126 a	126 a	126 a	152 a	154 a	153 a
$LSD_{0.05}$	NS	0.7	*0.6*	0.9	0.9	0.6	0.8	1.0	0.6
Amendments (A)									
No-amendments	10 a	10 a	10 a	123 c	124 c	124 b	151 a	151 c	151 c
Min-N	10 a	10 a	10 a	125 a	126 a	125 a	152 a	154 a	153 a
Humic acid	10 a	10 a	10 a	124 b	125 b	125 a	151 a	153 b	152 b
Effective microbes	9 a	9 a	9 a	125 a	126 a	125 a	152 a	153 b	152 b
$LSD_{0.05}$	NS	NS	*NS*	0.8	0.8	0.6	NS	0.9	0.6
Means of the years	10 a	10 a		124 b	125 a		151 b	153 a	
Significance_									
Years (Y)	-	-	NS	-	-	**	-	-	**
FYM	NS	**	**	*	**	**	*	**	**
A	NS	NS	NS	*	**	**	NS	*	**
FYM × A	NS	NS	NS	NS	NS	NS	NS	*	*
Y × FYM	-	-	NS	-	-	NS	-	-	NS
Y × A	-	-	NS	-	-	NS	-	-	NS
Y × FYM × A	-	-	NS	-	-	NS	-	-	NS

*Min-N was added @ 30 kg N ha^{-1}; Humic acid @ 2.5 ha^{-1}; Effective microbes @ 200 L Mg^{-1} FYM; NS: Non-significant at $P \leq 0.05$; * Significant at $P \leq 0.05$ and ** Significant at $P \leq 0.01$. Means within each category sharing common letter (s) are non-significant at $p \leq 0.05$ following LSD test.*

FYM ha^{-1} were applied than No FYM addition. The addition of FYM in the following year, and the accumulated manure from the last year might have increased the soil permeability, made the soil surface soft for emergence in addition to increase soil moisture (Saikia *et al*., 2015) and regulated soil temperature (Li *et al*., 2013), and thus had decreased days to emergence of wheat.

Wheat anthesis entirely depends on vegetative growth (Zhang *et al*., 2015), which itself is affected by nutrients availability (Khan *et al*., 2019a) and crop stand (Ibrahim and Khan, 2017). It was observed that increasing the FYM had increased the mineral N availability (Khan *et al*., 2019a), and other macro and micronutrients (Bowles *et al*., 2014), and thus had delayed the anthesis stage. The addition of Min-N itself (Khan *et al*., 2009) or increased N availability as a result of improved microbial activity in response to effective microbes addition (Mukherjeeand Zimmerman, 2013) had increased soil mineral N (Khan *et al*., 2019a), thereby increased the vegetative growth (Ibrahim and Khan, 2017; Khan *et al*., 2019b) and thus anthesis delayed. The increased root growth with increasing the nutrients (Zhang *et al*., 2015) may be another possible explanation for increased vegetative growth and delayed anthesis.

The physiological maturity is directly related to the environmental temperature (Olesen *et al*., 2012) and indirectly to the plant vegetative growth (Khan *et al*., 2008). The addition of higher levels of FYM had increased the nutrients availability particularly the nitrogen (Khan *et al*., 2019a), which increased the leaf vegetative growth (Khan *et al*., 2019b), and thus prolonged the days to physiological maturity stage in wheat. The repeated addition of effective microbes had increased the soil microbial biomass (Ali *et al*., 2019), increased the nutrients availability (Khan *et al*., 2019a), which delayed the vegetative growth (Khan *et al*., 2019b) and thus might have increased the days taken to physiological maturity. The addition of

Table 3: *Growth and stand of wheat as affected by farmyard manure addition modulated by various amendments during 2016-17 (Year I) and 2017-18 (Year II).*

Treatments	Crop growth and stand establishment								
	Leaf area tiller^{-1}(cm^2)			Plant height (cm)			Emergence m^{-2}		
Farmyard manure (FYM, Mg ha^{-1})	Year I	Year II	Mean	Year I	Year II	Mean	Year I	Year II	Mean
0	90.2 d	89.7 d	89.9 d	90.6 d	91.4 b	91.0 d	112 b	109 c	111 c
5	93.6 cd	98.5 c	96.1 c	93.0 c	94.3 ab	93.6 c	119 a	115 b	117 b
10	97.8 bc	102.1 bc	100.0 b	94.1 bc	95.0 a	94.5 bc	119 a	122 a	120 ab
15	101.2 ab	105.7 ab	103.5 a	95.6 ab	95.7 a	95.7 ab	120 a	123 a	122 a
20	104.0 a	107.8 a	105.9 a	96.4 a	96.5 a	96.5 a	121 a	126 a	123 a
LSD$_{0.05}$	4.8	5.0	3.5	2.2	2.8	1.8	5	4	3
Amendments (A)									
No-amendments	93.7 b	93.4 b	93.5 c	93.3 a	92.3 b	92.8 b	115 a	114 c	114 b
Min-N	96.4 ab	101.1 a	98.8 b	94.7 a	95.1 a	94.9 a	119 a	119 b	119 a
Humic acid	99.2 a	102.9 a	101.1 ab	93.6 a	94.4 ab	94.0 ab	120 a	120 ab	120 a
Effective microbes	100.2 a	105.6 a	102.9 a	94.2 a	96.6 a	95.4 a	120 a	123 a	121 a
LSD$_{0.05}$	4.3	4.5	3.1	NS	2.5	1.6	NS	4	3
Means of the years	97.4 b	100.8 a		93.9 a	94.6 a		118 a	119 a	
Significance									
Years (Y)	-	-	**	-	-	NS	-	-	NS
FYM	**	**	**	*	**	**	*	**	**
A	*	**	**	NS	*	*	NS	**	**
FYM × A	NS	NS	NS	NS	NS	NS	NS	**	*
Y × FYM	-	-	NS	-	-	NS	-	-	*
Y × A	-	-	NS	-	-	NS	-	-	NS
Y × FYM × A	-	-	NS	-	-	NS	-	-	NS

*Min-N was added @ 30 kg N ha^{-1}; Humic acid @ 2.5 ha^{-1}; Effective microbes @ 200 L Mg^{-1} FYM; NS: Non-significant at $P \leq 0.05$; * Significant at $P \leq 0.05$ and ** Significant at $P \leq 0.01$. Means within each category sharing common letter (s) are non-significant at $p \leq 0.05$ following LSD test.*

effective microbes had stimulated the decomposition of added manure and thus had increased the nutrients availability (Liu *et al*., 2010), improved the vegetative growth (Khan *et al*., 2019b) due to transferring of the metabolites and its translocation to the vegetative tissues (Khan *et al*., 2014) and thus might have prolonged the period for days to physiological maturity.

Crop growth and stand establishment

Increasing FYM from 0 to 20 Mg ha^{-1} had improved the leaf area by 15-20%. The increased manure application means increasing the net nitrogen and other nutrients availability upon decomposition. The increased availability of mineral N increased the photosynthetic efficiency of the plants (Akhtar *et al*., 2019b; Khan *et al*., 2019b) and thus increase the cell size and number (Keller and Koblet, 2015), and thus the leaf area of plants. The effective microbes had increased the mineralization of manure, and thereby increased the nutrients availability (Pan *et al*., 2018), which improved the leaf areas due to the vagarious crop growth.

Plant tallness depends on the vigorous plant growth and development (Walker *et al*., 2004). The increased nutrients availability as a result of greater manure addition increased the nutrients uptake (Akhtar *et al*., 2019c; Wen *et al*., 2016), photosynthetic efficiency (Saikia *et al*., 2015), and thus the plant height. The addition of effective microbes has increased the plant tallness by 5% over No-amendment. The effective microbes had increased the decomposition and increased the nutrients availability (Fang *et al*., 2018). The higher nutrients availability might have improved the vegetative growth of plants (Wen *et al*., 2016), increased the leaf area (Keller and Koblet, 2015), and thus had increased the plant tallness.

Table 4: *Biomass (kg ha⁻¹) of wheat as affected by farmyard manure (FYM) addition modulated by various amendments over years.*

Treatments	Years (Y)		Mean
	2016-17	2017-18	
FYM (tons ha^{-1})			
0	9204 c	9523 c	9363 d
5	9821 b	9838 c	9829 c
10	10109 ab	10666 b	10387 b
15	10484 a	11292 ab	10888 a
20	10453 a	11783 a	11118 a
$LSD_{0.05}$	558	735	465
Amendments (A)			
No-amendments	9750 b	9838 c	9794 c
Min-N	9718 b	10517 b	10118 bc
Humic acid	10027 b	10741 ab	10384 b
Effective microbes	10561 a	11386 a	10973 a
$LSD_{0.05}$	499	658	416
Mean	10014 b	10620 a	
Y	-	-	**
FYM	**	**	**
A	**	**	**
FYM × A	NS	NS	NS
Y × FYM	-	-	NS
Y × A	-	-	NS
Y × FYM × A	-	-	NS

*Min-N was added @ 30 kg N ha^{-1}; Humic acid @ 2.5 ha^{-1}; Effective microbes @ 200 L Mg^{-1} FYM. NS: Non-significant at $P \leq 0.05$; * Significant at $P \leq 0.05$ and ** Significant at $P \leq 0.01$. Means within each category sharing common letter (s) are non-significant at $p \leq 0.05$ following LSD test.*

Crop emergence m^{-2} entirely depends on seed vigor and its germination (Vashisth and Nagarajan, 2010), soil physical condition like moisture availability and temperature (Lin *et al*., 2019) etc. The addition of FYM had improved the soil moisture, regulated soil temperature (Zavattaro *et al*., 2017) and improved soil properties (Odlare *et al*., 2008), and thus might have improved the wheat emergence m^{-2}. The repeated application of FYM over two years had changed the soil physico-chemical properties like improvement in soil moisture content, infiltration, bulk density (Guo *et al*., 2016) and porosity (Abbas and Fares, 2009), consequently, the seed germination and emergence increased. Emergence m^{-2} sharply increased with No-amendments as compared to Min-N with increasing FYM from 0 to 10 Mg ha^{-1}. However, using 10 Mg FYM ha^{-1} or above, no differences in emergence m^{-2} was noted among the amendments. This indicates that even 10 Mg FYM ha^{-1}can cause enough changes in soil properties over two years, that can increase emergence of plants.

Wheat biomass

The biomass was significantly ($p \leq 0.05$) higher in year-II than year-I. The repeated addition of manure and its residual effect (Grant *et al*., 2016) has increased the nutrients availability (Khan *et al*., 2019a)and hence the plant vegetative growth and dry matter production (Khan *et al*., 2014) and biomass production. In both years, the FYM application significantly ($p \leq 0.05$) improved the biomass with all levels of FYM. Increasing the FYM up to 15 Mg ha^{-1} had significantly ($p \leq 0.05$) increased the biomass (13.9%) in year-I, however in year-II, the increases were 23.7% when FYM increased from 0 to 20 Mg ha^{-1}. The higher manure addition assumed to have improved the soil properties including physico-chemical and biological (Akhtar *et al*., 2019a), increased nutrients availability (Akhtar *et al*., 2019c), and thereby improved the photosynthetic activity (Saikia *et al*., 2015), plant dry matter (Khan *et al*., 2014) and hence the biomass production. The addition of effective microbes has significantly ($p \leq 0.05$) increased the biomass over humic acid, Min-N or No-amendments treatment in Year-I. However, in year-II, the organic amendments had significantly ($p \leq 0.05$) higher biomass than Min-N and No-amendments. The effective microbes increased the microbial biomass (Liu *et al*., 2010) and hence availability of nutrients via stimulated decomposition (Odlare *et al*., 2008). The increased nutrients have greater potential for improving the plant growth and development (Khan *et al*., 2014) via increasing the photosynthetic activities (Khan *et al*., 2015), and hence the biomass production. The other possible reasons for improving the biomass is the improvement in soil properties (Khan *et al*., 2019a), rhizosphere condition and usage efficiencies of the nutrients (Federolf *et al*., 2016). Biomass production is a function of individual plant performance, and thus addition of microbes has increased the individual plant performance, thus had increased the biomass.

Conclusions and Recommendations

It was concluded that increasing the FYM from 0 to 15 Mg ha^{-1}, the phenological observation delayed, but the wheat leaf area, stand establishment and biomass increased. However, with further increase in FYM, no statistical ($P \leq 0.05$) differences in plants measured parameters were noted. Quantitatively, the physiological maturity delayed by 2 days with 20 Mg FYM ha^{-1} over No FYM. However, the leaf area increased by 17% and biomass by 16%, with increasing FYM from 0 to 15 Mg ha^{-1}. Likewise, the addition of effective microbes has prolonged the phenological observation and improved wheat leaf area, stand establishment and biomass. It was noted that the plant performance in term of delayed phenology, and improved growth/biomass was in the order of min-N > HA ~ EM > no-amendment. The application of 15-20 Mg FYM ha^{-1} amended with effective microbes is recommended for improved crop growth and stand establishment of wheat in the studied areas.

Novelty Statement

Crop stand and biomass improved with effective microbes and manure addition Phenological observation delayed with increasing farmyard manure. The addition of effective microbes enhanced crop stand and biomass when added with 15-20 Mg FYM ha^{-1}

Author's Contribution

Anjum carried out research and drafted the manuscript. A. Khan carried out the analysis, conceived the idea and supervised the research.

Conflict of interest

The authors have declared no conflict of interest.

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