Research Article

Application of Organic Sources and Nitrogen affect Dry Matter Partitioning in Wheat under Tillage Systems

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Abstract | Organic manure and mineral nitrogen both plays an important role in improving soil fertility and crop productivity. Field experiment was conducted at The Agronomy Research Farm of The University of Agriculture Peshawar, during winter 2015 to investigate the effect of organic sources (cattle, sheep and poultry manure each at 5 t ha^{-1}) and nitrogen levels (0, 75, 100, 125 and 150 kg ha^{-1}) on dry matter partitioning of wheat under tillage systems (conventional and deep tillage). The experiment was laid out in randomized complete block design with split plot arrangement, having three replications. Tillage systems and organic sources were used as main plot factor, nitrogen levels as subplot factor. The results revealed that organic sources, nitrogen levels and tillage system significantly affected dry matter partitioning of wheat. Application of poultry manure improved dry matter partitioning into different plant parts at heading and physiological maturity as compared to sheep and cattle manure. Application of nitrogen at the higher rates (125 to 150 kg N ha^{-1}) enhanced dry matter partitioning at heading and physiological maturity than lower N rates and control. Likewise, wheat sown with deep tillage system resulted in increased dry matter partitioning into different plant parts than conventional tillage system. We concluded from this study that integrated use of inorganic nitrogen (125 kg N ha^{-1}) and poultry manure (5 ton ha^{-1}) improve dry matter partitioning of wheat under deep tillage system.

Received | November 19, 2017; **Accepted** | June 01, 2018; **Published** | June 08, 2018
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Citation | Alamzeb, M., S. Anwar, A. Iqbal, S. Meizhen, M. Iqbal, Sara, M. Ramzan and A. Tabassum. 2018. Application of organic sources and nitrogen affect dry matter partitioning in wheat under tillage systems. *Pakistan Journal of Agricultural Research,* 31(2): 106-115.
DOI | http://dx.doi.org/10.17582/journal.pjar/2018/31.2.106.115
Keywords | Wheat, Dry matter partitioning, Organic sources, Nitrogen levels, Tillage system

Introduction

Wheat (*Tritium aestivum* L.) is the most important cereal crop in the world and also in Pakistan. In Pakistan, it is key staple food crop among cereals (Kakar et al., 2015 a) which occupies about 37% of the cropped area and consumes about 45% of the total fertilizers utilized in the country (Malik et al., 2006; Amanullah et al., 2017 a). In Pakistan wheat contributes 14.4% share in agriculture and 3% in gross domestic products (Kakar et al., 2015 b). It was cultivated on an area of 9180 thousand hectares with the average yield of 2852 kg ha^{-1} during 2014–2015 (MNFS and R, 2014-15).

Dry matter is one of the measures of plant growth (Noggle and Fritz, 1983) and it reflects the relative growth rate as regards to net assimilation rate

(Ibeawuchi, 2004). Jones (1976) stated that dry matter can be influenced by farmyard manure application and this is a function of crop species and soil fertility. Ramamurthy and Shivashankar (1996) in their experiment found that organic matter improved the dry matter production at different stages of crop growth and yield attributing characters of corn. The use of dairy manure not only increases the soil inorganic N pool, but also increases the seasonal soil N mineralization available to the crops (Chang et al., 1993; Murwira and Kirchmann, 1993; Ma et al., 1999).

Many organic materials (sheep, cow, and poultry manure) are used in crop production as a substitute to synthetic fertilizers and their role in crop productivity cannot be ignored (Abbas et al., 2012; Alamzeb et al., 2017). The soil organic matter (SOM) is important for maintaining soil fertility and productivity. Soils in Pakistan contain low levels of SOM, usually less than 10 g kg^{-1} (GOP, 2013), compared to optimum levels of 25-30 g kg^{-1} for productive soils (Islam, 2006). The application of organic fertilizers together with chemical fertilizer is, therefore, necessary to sustain soil fertility and the levels of SOM required for sustainable high yields. Integrated nutrient management is a rational strategy (Palm et al., 1997) that reduces losses by converting inorganic N into organic form (Kramer et al., 2002), increases the efficiency of the fertilizers and reduces the environmental problems that may arise due to use of the inorganic source. Poultry manure is another potential source of organic fertilizer. This can be used as an effective organic fertilizer, because it contains high levels of all macronutrients required for plant growth and improves the soil physical and chemical properties by increasing SOM content. Sustainable agricultural management such as incorporation of different organic sources in soils is urgently needed to enhance crop production under cereal based cropping systems (Amanullah et al., 2017 b).

Nitrogen management is one of the most important factors for improving crop productivity under semiarid climates (Amanullah et al., 2016 b). Among plant nutrients, nitrogen has been considered as a major growth and development element (Nikolic et al., 2012). It is one of the most important nutrients for crop production as it affects dry matter production by influencing leaf area development and maintenance as well as photosynthetic efficiency (Muchow, 1988). Dry matter production increased linearly with N application (O'Leary and Rehm, 1990) up to 200 kg N ha^{-1}. Nitrogen stress restricted growth of wheat plants and their dry matter production (Arduini et al., 2006). Optimum availability of N to wheat plant results in promising plant growth (Ahmad et al., 2012) and higher yield (Ali et al., 2012) compared to improperly fertilized plants. Waraich et al. (2002) observed that increased N results in maximum leaf area index, number of tillers, net assimilation rate, relative growth rate, grain weight and grain yield. Nitrogen is responsible for shoot and root growth (Comfort et al., 1988) and grain formation (Arduini et al., 2006). High nitrogen treatment increased shoot dry matter (Masoni et al., 2007; Laghari et al., 2010). Latiri et al. (1998) reported that nitrogen stimulated dry matter production substantially due to increased leaf area index, which resulted in improved efficiencies of radiation and water use.

One of the modifiers of soil structure is tillage practice. Tillage may have direct or indirect impact on plant development (Khan et al., 2008) other than root growth (Wilhelm, 1998). In terms of crop productivity, dry-matter partitioning and leaf area development are critical factors determining light interception, and through it, crop yield (Milthorpe and Moorby, 1974). Reduced tillage practices were used to fruitfully increase the phosphorus and intensify the cropping intensity per year (Halvorson and Reule, 1994; Halvorson et al., 2000) and hence crop yield. In the same way, tillage systems are used for seedbed preparation (Lal and Kimble, 1997). Researchers reported that deep tillage or conventional tillage practices improve soil porosity (D´ıaz-Zorita, 2000; Hao et al., 2001), aeration (D´ıaz-Zorita, 2000), conserve and make more soil moisture, and improve nutrients' availability (L´opez-Bellido et al., 2001; Patil and Sheelavantar, 2006) compared to no tillage system. Deep tillage (30 cm) disrupts water impeding layers down in soil profile, conserve rainwater and increase grain yield and water use efficiency (Shaheen et al., 2010).

Nitrogen and organic matter (Iqbal et al., 2017) are the major limiting factors of crop production in Northern Pakistan, Khyber Pakhtunkhwa (KP). The integrated use of nitrogen (N), organic sources (OS) and tillage (T) could enhance crop productivity. However, there is no research to investigate the interactive effects of N x OS x T in KP. This research was therefore designed to study the interactive effect of N x OS x Ton dry matter partitioning of wheat in the semiarid climate of Pakistan.

Materials and Methods

Field experiment was conducted at Agronomy Research Farm of The University of Agriculture Peshawar, during winter 2015 with the objectives to investigate the effect of organic sources and nitrogen levels on dry matter partitioning of wheat under tillage systems. The experiment was laid out in randomized complete block design with split plot arrangement, having three replications. Tillage systems {deep plough (mould board plough) and conventional plough (cultivator)} and organic sources (poultry, sheep and cattle manure each applied at the rate of 5 ton ha^{-1}) were used as main plot factors. Nitrogen levels (0, 75, 100, 125 and 150 kg N ha^{-1}) were applied to subplots. A subplot size 3 x 2.5 m, having 8 rows, 2.5 m long and 30 cm apart was used. Different nitrogen levels were applied from urea in two equal splits, that is, half at sowing and half at tillering stage. Wheat cultivar Pirsabak-2013 was used as a test crop. All other agronomic practices (Phosphorus, weeding, irrigation, chemicals, harvesting etc.) were uniform for all the treatments.

Data was recorded on dry matter partitioning at heading and physiological maturity. For data on dry matter partitioning at heading and physiological maturity, plants from 1 meter at each stage were harvested. Leaves, stem, spike were separated. The materials were sun dried up to constant weight and weighed by electronic balance to determine the dry weight of leaf, stem and spike per meter.

Statistical analysis

Data were statistically analyzed according to Steel et al. (1996) and means were compared using LSD test ($P \leq 0.05$).

Results and Discussion

Leaf dry matter at heading (g m^{-2})

Leaf dry matter at heading was significantly affected by organic sources, nitrogen, tillage systems and T x N, while the rest of interactions had non-significant effect on leaf dry matter of wheat (Table 1). Application of poultry manure improved leaf dry matter at heading (106.0 g m^{-2}), while lower dry matter at heading was obtained from cattle manure (102.4 g m^{-2}). Similarly, increased in leaf dry matter at heading was recorded from nitrogen at highest levels 150 kg N ha^{-1} (108.5 g m^{-2}) which was at par with 125 kg N ha^{-1} (107.8 g m^{-2}), while the less leaf dry matter (96.3 g m^{-2}) was recorded from control plot. The deep tillage system produced highest leaf dry matter (106.3 g m^{-2}) than the conventional tillage system (101.8 g m^{-2}). Deep tillage system along with higher N rates increased leaf dry matter (g m^{-2}) of wheat T x N (Figure 1).

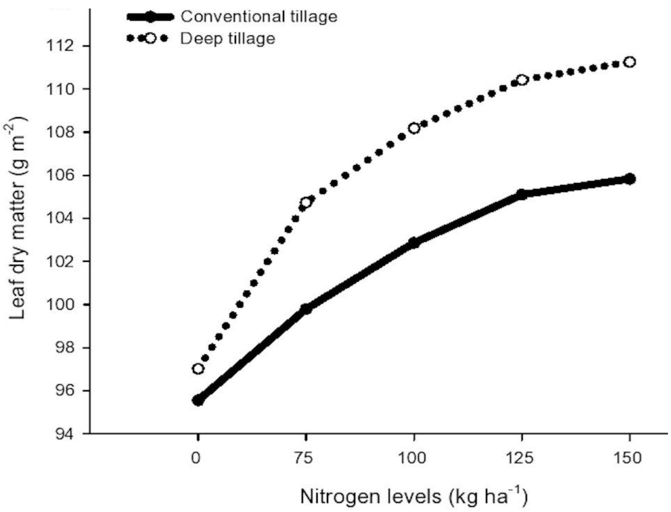

Figure 1: *Interactive effect of nitrogen levels and tillage system on leaf dry matter (g m^{-2}) of wheat at heading.*

Stem dry matter at heading (g m^{-2})

Data related to stem dry matter at heading are showed in Table 1. The mean data showed that organic sources, nitrogen, tillage systems, T x N and T x OS had significant effect on stem dry matter of wheat. Application of poultry manure improved stem dry matter at heading (344.6 g m^{-2}), while lower stem dry matter at heading was obtained from cattle manure (338.5 g m^{-2}). Similarly, increased in stem dry matter at heading was recorded from nitrogen at highest levels 150 kg N ha^{-1} (363.4 g m^{-2}), while the least stem dry matter (281.0 g m^{-2}) was noted in control plot. The deep tillage system produced highest stem dry matter (344.0 g m^{-2}) than the conventional tillage system (338.8 g m^{-2}). Deep tillage system along with poultry manure (5 t ha^{-1}) increased stem dry matter (g m^{-2}) of wheat T x OS (Figure 2). Deep tillage system along with higher N rates increased stem dry matter (g m^{-2}) of wheat T x N (Figure 3).

Spike dry matter at heading (g m^{-2})

The mean data showed that organic sources, nitrogen, tillage systems had significant, while the interaction had non-significant effect on spike dry matter at heading of wheat (Table 1). Maximum spike dry matter at heading (110.9 g m^{-2}) was produced by poultry manure, which was statically at par with sheep manure, while lower spike dry matter at heading was obtained from cattle manure (108.6 g m^{-2}). Similarly, increased in spike dry matter at heading was recorded from nitrogen at highest levels 150 and 125 kg N ha^{-1} (112.1 and 111.4 g m^{-2} respectively), while the lowest spike dry matter (106.5 g m^{-2}) was recorded from control plot. The deep tillage system produced highest spike dry matter (110.9 g m^{-2}) than the conventional tillage system (108.6 g m^{-2}).

Table 1: *Leaf dry matter (g m^{-2}), stem dry matter (g m^{-2}), spike dry matter (g m^{-2}), total dry matter (g m^{-2}) at heading of wheat as affected by organic sources, nitrogen levels and tillage systems.*

Organic sources (tons ha^{-1})	Leaf dry matter (g m^{-2})	Stem dry matter (g m^{-2})	Spike dry matter (g m^{-2})	Total dry matter (g m^{-2})
Cattle	102.4 c	338.5 c	108.6 b	549.5 c
Sheep	103.8 b	341.2 b	109.8 ab	554.9 b
Poultry	106.0 a	344.6 a	110.9 a	561.5 a
LSD	1.3	1.2	1.6	2.2
Nitrogen (kg ha^{-1})				
0	96.3 d	281.0 e	106.5 d	483.8 e
75	102.3 c	349.4 d	108.8 c	560.5 d
100	105.5 b	353.1 c	110.1 b	568.7 c
125	107.8 a	360.3 b	111.4 a	579.4 b
150	108.5 a	363.4 a	112.1 a	584.1 a
LSD	1.1	1.7	1.3	2.9
Tillage				
Conventional	101.8 b	338.8 b	108.6 b	549.3 b
Deep	106.3 a	344.0 a	110.9 a	561.3 a
LSD	1.0	1.0	1.3	1.8
Interactions				
T x OS	ns	* (Fig. 2)	ns	* (Fig. 4)
T x N	** (Fig. 1)	** (Fig. 3)	ns	** (Fig. 5)
OS x N	ns	ns	ns	ns
T x OS x N	ns	ns	ns	ns

Means of the same category followed by different letters are significantly different from each other using LSD test (P ≤ 0.05).
*Where: ns stands for non-significant data, while ** and * indicates significant at 1 and 5% level of probability, respectively using LSD test (P ≤ 0.05).*

Total dry matter at heading (g m^{-2})

Total dry matter of wheat as affected by organic sources, nitrogen, tillage systems, T x OS and T x N interaction are given in Table 1. Application of poultry manure improved total dry matter at heading (561.5 g m^{-2}), while lower total dry matter at heading was obtained from cattle manure (549.5 g m^{-2}). Similarly, increased in total dry matter at heading was recorded from nitrogen at highest levels 150 kg N ha^{-1} (584.1 g m^{-2}), while the lowest total dry matter (483.8 g m^{-2}) was recorded from control plot. The deep tillage system produced highest total dry matter (561.3 g m^{-2}) than the conventional tillage system (549.3 g m^{-2}). Deep tillage system along with poultry manure (5 t ha^{-1}) increased total dry matter (g m^{-2}) of wheat T x OS (Figure 4). Deep tillage system along with higher N rates increased total dry matter (g m^{-2}) of wheat T x N (Figure 5).

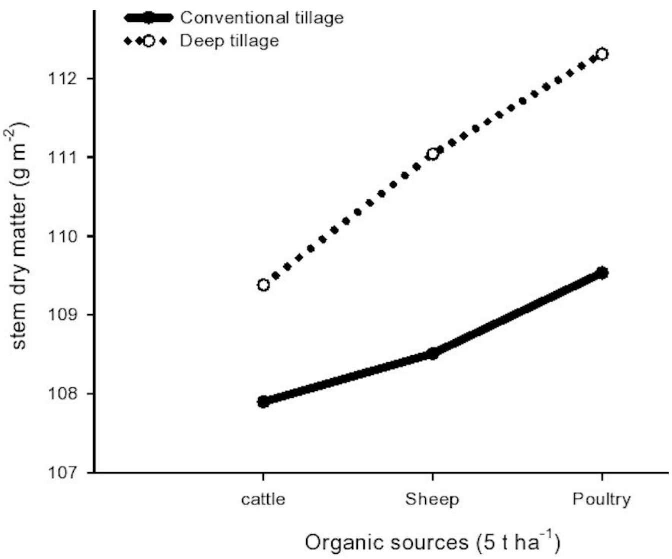

Figure 2: *Interactive effect of organic sources and tillage system on the stem dry matter (g m^{-2}) of wheat at heading.*

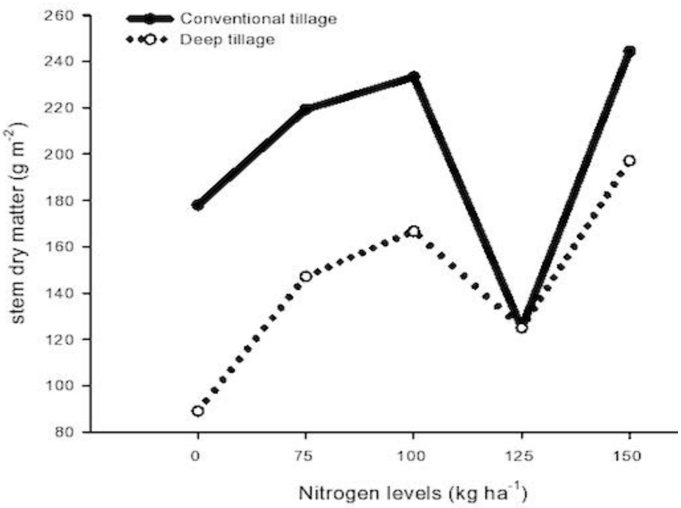

Figure 3: *Interactive effect of nitrogen levels and tillage system on stem dry matter (g m^{-2}) of wheat at heading.*

Leaf dry matter at physiological maturity (g m^{-2})

The mean data showed that organic sources, nitrogen, tillage systems and T x N had significant effect on leaf dry matter of wheat (Table 2). Application of poultry manure improved leaf dry matter at physiological maturity (73.2 g m^{-2}), while minimum leaf dry matter at physiological maturity was obtained from cattle manure (70.0 g m^{-2}). Similarly, increased in leaf dry matter at physiological maturity was recorded from nitrogen at highest levels 150 kg N ha^{-1} (75.5 g m^{-2}) which was similar to 125 kg N ha^{-1} (74.9 g m^{-2}), while the lowest leaf dry matter (64.4 g m^{-2}) was recorded from control plot. The deep tillage system produced highest leaf dry matter (73.6 g m^{-2}) than the conventional tillage system (69.4 g m^{-2}). Deep tillage system along with higher N rates increased leaf dry matter at physiological maturity (g m^{-2}) of wheat T x N (Figure 6).

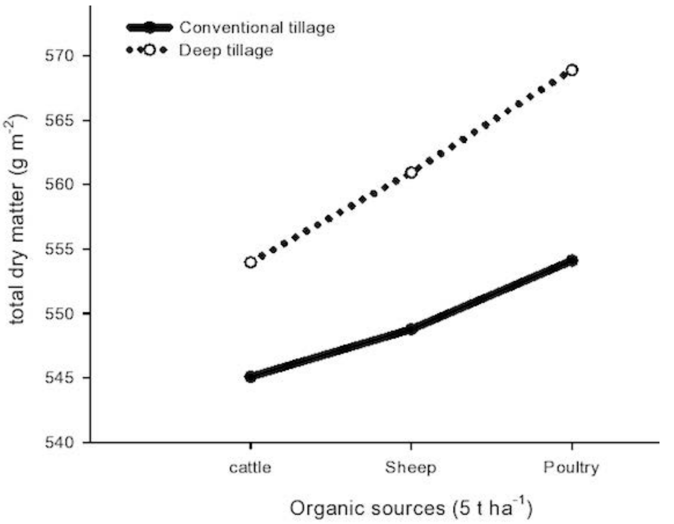

Figure 4: *Interactive effect of nitrogen levels and tillage system on total dry matter (g m^{-2}) of wheat at heading.*

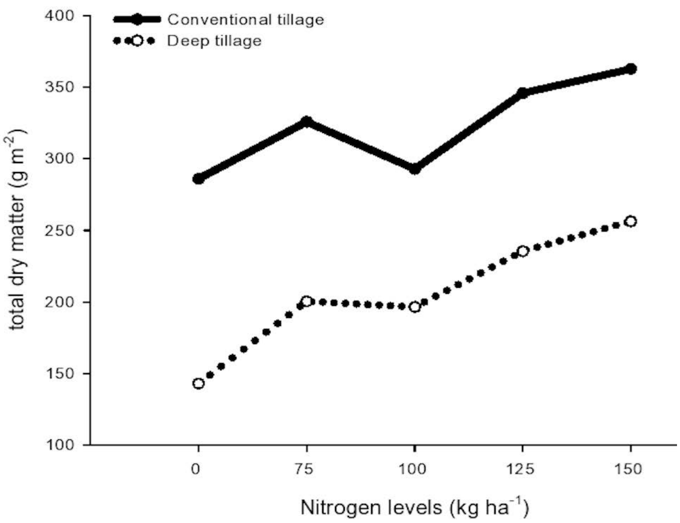

Figure 5: *Interactive effect of nitrogen levels and tillage system on total dry matter (g m^{-2}) of wheat at heading.*

Stem dry matter at physiological maturity (g m^{-2})

Perusal of the data revealed that stem dry matter at physiological maturity was significantly affected by organic sources, nitrogen and tillage systems Table 2. Application of poultry manure improved stem dry matter at physiological maturity (485.3 g m^{-2}), while lower dry matter at physiological maturity was obtained from cattle and sheep manure (482.6 and 483.8 g m^{-2} respectively). Similarly, increased in stem dry matter at physiological maturity was recorded from nitrogen at highest levels 150 kg N ha^{-1} (520.7 g m^{-2}) which was comparable with 125 kg N ha^{-1} (519.7 g m^{-2}), while the minimum stem dry matter (347.1 g m^{-2}) was recorded from control plot. The deep tillage system produced highest stem dry matter (484.7 g m^{-2}) than the conventional tillage system (483.2 g m^{-2}).

Table 2: *Leaf dry matter (g m^{-2}), stem dry matter (g m^{-2}), spike dry matter (g m^{-2}), total dry matter (g m^{-2}) at physiological maturity of wheat as affected by organic sources, nitrogen levels and tillage systems.*

Organic sources (ton ha^{-1})	leaf dry matter (gm^{-2})	stem dry matter (gm^{-2})	spike dry matter (gm^{-2})	total dry matter (gm^{-2})
Cattle	70.0 c	482.6 b	600.3 b	1152.9 c
Sheep	71.3 b	483.8 b	603.0 ab	1158.1 b
Poultry	73.2 a	485.3 a	606.6 a	1165.2 a
LSD	1.2	1.2	3.1	3.3
Nitrogen (kg ha^{-1})				
0	64.4 d	347.1 d	406.2 d	817.7 d
75	69.9 c	514.9 c	647.0 c	1231.9 c
100	72.8 b	517.1 b	651.2 b	1241.2 b
125	74.9 a	519.7 a	655.2 ab	1249.8 a
150	75.5 a	520.7 a	656.9 a	1253.2 a
LSD	1.2	1.1	3.4	4.1
Tillage				
Conventional	69.4 b	483.2 b	600.4 b	1153.0 b
Deep	73.6 a	484.7 a	606.2 a	1164.5 a
LSD	1.0	1.0	2.5	2.7
Interactions				
T x OS	ns	ns	ns	ns
T x N	** (Fig. 6)	ns	ns	ns
OS x N	ns	ns	ns	ns
T x OS x N	ns	ns	ns	ns

Means of the same category followed by different letters are significantly different from each other using LSD test ($P \leq 0.05$).
*Where: ns stands for non-significant data, while ** indicates significant at 1 level of probability, respectively using LSD test ($P \leq 0.05$).*

Spike dry matter ast physiological maturity (g m^{-2})

From the mean data it is cleared that incorporation of poultry manure improved spike dry matter at physiological maturity (606.6 g m^{-2}), while lower dry matter at physiological maturity was obtained from cattle manure (600.3 g m^{-2}). Similarly, increased in spike dry matter at physiological maturity was recorded from nitrogen at highest levels 150 kg N ha^{-1} (656.9 g m^{-2}) which was similar to 125 kg N ha^{-1} (655.2 g m^{-2}), while the least spike dry matter (406.2 g m^{-2}) was recorded from control plot. The deep tillage system produced highest spike dry matter (606.2 g m^{-2}) than the conventional tillage system (600.4 g m^{-2}) (Table 2).

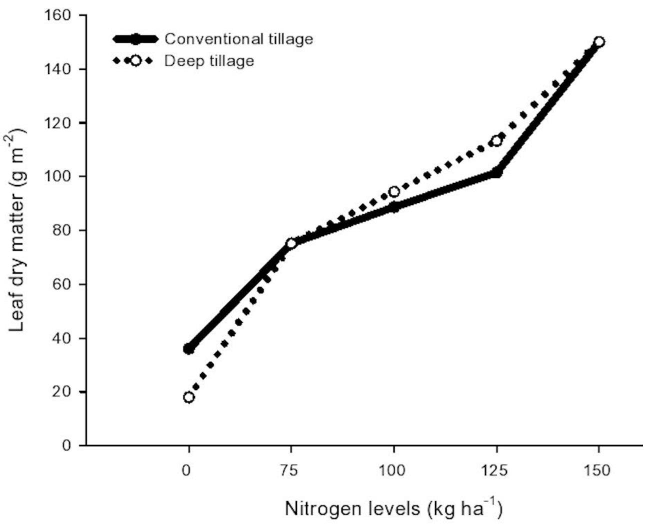

Figure 6: *Interactive effect of nitrogen levels and tillage system on leaf dry matter (g m^{-2}) of wheat at physiological maturity.*

Total dry matter at physiological maturity (g m^{-2})

Application of poultry manure improved total dry matter at physiological maturity (1165.2 g m^{-2}), while minimum dry matter at physiological maturity was obtained from cattle manure (1152.9 g m^{-2}). Similarly, increased in total dry matter at physiological maturity was recorded from nitrogen at highest levels 150 kg N ha^{-1} (1253.2 g m^{-2}) which was alike to 125 kg N ha^{-1} (1249.8 g m^{-2}), while the lower total dry matter (817.7 g m^{-2}) was recorded from control plot. The deep tillage system produced highest total dry matter (1164.5 g m^{-2}) than conventional tillage system (1153.0 g m^{-2}) (Table 2).

Dry matter partitioning into various plant parts (leaves, stem and spike) at heading and maturity was significantly affected by organic sources, nitrogen levels and tillage systems. Incorporation of poultry manure increased dry matter partitioning into different plant parts as compared to sheep and cattle manure. Application of manure improve nutrients availability and also increases water holding capacity of the soil which ultimately increase growth and dry matter (Manhas and Gill, 2010; Rashid et al., 2013). According to several researchers Mhlontlo et al. (2007), Ramesh et al. (2011), Mishra and Jain (2013) reported increase in dry matter with application of sheep manure. Iqbal et al. (2015) and Amanullah et al. (2016 a) also reported that manure incorporated plots produced more dry matter in maize as compared to plots having no manure treatments. Ezeibekwe et al. (2009) and Ofosu-Anim and Leitch (2009) also reported that dry matter production and assimilation in plants under chicken manure was the maximum than control. The better performances associated with the poultry manure over other manures has been shown by many agronomic plants (Hussein, 1997). Detpiratmongkol et al. (2014) compared different organic manures and reported that the maximum stem dry weight was obtained in plots under chicken manure whereas the cattle manure gave the lowest stem dry weight. The trend of increasing leaf dry weight with the application of organic manure was earlier reported by Goenadi (1985). Nitrogen applied at higher levels (125 kg N ha^{-1}) improved dry matter partitioning into different plant parts at heading and physiological maturity. Morgan et al. (2001) revealed that addition of N increased biomass accumulation in plants. Dry matter yields increased with the application of manure and inorganic fertilizers than the untreated control (Mhlontlo et al., 2007). Similarly, many researchers have reported that dry matter increased with increase in N application than that of control plots (Shah et al., 2009; Amanullah et al., 2015 a). Laghari et al. (2013) revealed that high nitrogen significantly increased total dry weight (42%), shoot dry weight (58%) and number of leaves on main stem (13%). This indicated that plant growth and development depend on nitrogen supply and in general increasing the nutrient enhances plant growth and development (Bauer et al., 1984; Nikolic et al., 2012). The nutrient supply and demand of root and shoot are inter-dependent due to their different functions and local environment (Li et al., 2001; Arduini et al., 2006; Hakim et al., 2012). N shortage and N excess affect assimilate partitioning between vegetative and reproductive organs (Subedi and Ma, 2005). Sufficient nitrogen supply significantly increased the amount of current photosynthesis and its contribution to dry matter and grain yield (Madani et al., 2010; Anwar et al., 2017). According to Alamzeb et al. (2017), inorganic nitrogen along with poultry manure under deep tillage maximize not only productivity but also profitability of wheat crop in semiarid climates. In the current study deep tillage performed better in term of dry matter partitioning at heading and physiological maturity than conventional tillage system. According to Amanullah et al.

(2015b and 2016c) more dry matter partitioning in maize crop was noted under deep tillage system over conventional tillage system.

Conclusion

In conclusion, our results showed changes in dry matter in response to the application of organic sources, nitrogen and tillage systems. Deep tillage influence on dry matter partitioning at heading and physiological maturity was more than conventional tillage system. Similarly higher dry matter production at different crop stage was associated with the application of poultry manure (5 ton ha^{-1}) and nitrogen at higher rates (125 and 150 kg ha^{-1}). For higher dry matter production combined use of poultry manure (5 ton ha^{-1}) and nitrogen (125 kg ha^{-1}) are recommended for wheat under deep tillage system in the semiarid regions.

Author's Contribution

Madeeha Alamzeb performed the experiment and took the data. Shazma Anwar conceived the idea. Asif Iqbal helped in data entry in SPSS, analysis and wrote the article. Song Meizhen, Mazhar Iqbal and Sara gave technical input at every step. Muhammad Ramzan and Afza Tabassum helped in overall management of the article.

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