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GREEN MANURE CROPS AND N RATES INFLUENCE ON VARIABILITY OF DRY MATTER AND N CONTENT AT ANTHESIS AND MATURITY IN WHEAT (*TRITICUM AESTIVUM* L.)

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Abstract

AYNEHBAND, A., F. GERAMI and E. FATEH, 2013. Green manure crops and n rates influence on variability of dry matter and n content at anthesis and maturity in wheat (*Triticum aestivum* L.). *Bulg. J. Agric. Sci.,* 19: 282-292

Efficient and economic utilization of green manure crops is crucial in sustainable agriculture. Field experiments were conducted to study the effect of nitrogen supply through chemical N fertilizer and green manures on grain yield and nitrogen loss and gain of wheat as subsequent crop. The experimental design was split plots, arranged in randomized complete block with three replications. Results showed that, green manure differences in dry matter and nitrogen translocation efficiencies were related to nitrogen and biomass accumulated in plant reserve parts at both anthesis and maturity. Green manure dry matter translocation efficiencies ranged from 18.7 in cowpea to 22.5% in amaranth, nitrogen translocation efficiencies from 73.9 in sesbania to 76.6% in amaranth and contribution of pre-anthesis assimilates to grains from 32.8 in millet to 43.5% in amaranth. It has to indicate that all of them were greatest in the non-legume green manures. Increase in N application, decreased the contribution of pre-anthesis assimilates to grains, but had various effect on N gain and losses. At the highest N application rates dry matter translocation efficiency, contribution of pre-anthesis assimilates to grain, nitrogen translocation efficiency, harvest index and nitrogen harvest index were greatest in amaranth (non-legume) green manure crops. But, at the optimum and lower N application rates (100 and 50 kg N ha^{-1}) this parameters were greatest in all legume green manure crops. In addition, greatest N losses also occurred at the highest N rates. Consequently, high amounts of N accumulated at anthesis led to worst N loss at maturity.

Key words: Green manure, nitrogen, wheat, dry matter, efficiency

Introduction

In recent years, fertilizer cost and concern for sustainable soil productivity and ecological stability in relation to chemical fertilizer use have emerged as important issues. There is a renewed interest in organic manures, such as farmyard manures, composts, and green manures, as sources of plant nutrients. The more readily available green manures constitute a valuable source of both N and organic matter (Dayegamiye and Tran, 2001).

The application of green manures to soil is considered a good management practice in any agricultural production system because can increase cropping system sustainability by reducing soil erosion and ameliorating soil physical properties, by increasing soil organic matter and fertility levels, by increasing nutrient retention, and by reducing global warming potential (Tejada et al., 2008). Leguminous and non-leguminous plants are used in the production of green manures. Leguminous plants form symbiotic associations with Rhizobium bacteria in order to ?x N2. This fact causes that the green manures, which their principal component are leguminous plant debris, supply to the soil important amounts of N in relation to the green manures obtained from non-leguminous plants. However, the influence of this organic matter on soil properties depends upon amount, type, size and dominant component of the added organic materials (Dayegamiye and Tran, 2001). Cultivation of green manure crops is the main

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possibility for soil enrichment with nutrients, especially with nitrogen. The productivity of cereals depends on soil properties, meteorological factors, fertilization, and especially humus content in soil. Ploughed-in green material enriches soil with organic matter, which as a result of microbiological processes releases nutrients for plants (Talgre et al., 2009).

The residues and ploughed-in green material of perennial grasses, as preceding crops, have a positive effect on the formation of productivity elements of cereal crops not only in the first year but also in the second year, which determines the productivity of the cereal link (Skuodien and Nekro?ien, 2007). The results suggest that, some leguminous crops are the optimum species for use as green manure. Green manure application has also been found to influence N cycling in soil. Green manures could have benefits for soil N dynamics by recovering residual mineral N in soil, by fixing N from the atmosphere for leguminous green manures, and thereby contributing to subsequent crop N nutrition. N release from green manure crop residues has been evaluated for maize and wheat (Sharma and Behera, 2010). On one hand, green manures with lower C/N ratios decompose rapidly and have a rapid effect on soil physical properties and on biological activity. On the other hand, more lignified green manures present lower decomposition rates and have smaller effects on N mineralization potentials than organic residues with lower C/N ratios (Dayegamiye and Tran, 2001).

The N content of grain grown without N fertilizer was highly significantly related to the reserves of available N in the soil. Growing cereals in a leguminous living mulch bi-cropping could potentially reduce the need for synthetic inputs in cereal production while preventing losses of nutrients and increasing soil biological activity (Cookson et al., 2002). In addition, grains are the most active sink for carbon and N assimilates in cereal after flowering. Whereas, most of the carbohydrates are provided by current photosynthesis, the major fraction of seed N is derived by mobilization of N accumulated before anthesis in vegetative organs (Cartelle et al., 2006). Studies have shown that grain N in wheat mainly represents N accumulated in the vegetative parts until anthesis and translocated to kernel during the reproductive phase. N distribution showed that 60 - 92% of the N accumulation in the wheat grain originates from mobilization from vegetative tissue after anthesis. In fact, in all grain crops the supply of assimilates to the developing grain originates both from current assimilation transferred directly to kernels and from the remobilization of assimilates stored temporarily in vegetative plant parts (Dordas, 2009). The reserves deposited in vegetative plant parts before anthesis may buffer grain yield when conditions become adverse to photosynthesis and mineral uptake during grain filling. The relative importance of current assimilation and remobilization changes among genotypes and is strongly related to environmental conditions (Tahir and Nakata, 2005).

In view of the above, the objective of this study was to evaluate the effect of different green manure crops at different N rates on nitrogen dynamic in wheat agro-ecosystem.

Materials and Methods

A field experiment was conducted on Research Station Farm at the Agricultural Faculty of Shahid Chamran University of Ahvaz, Iran, (31°20’ N latitude and 48°41’ E longitudes) at an elevation of 20 m above mean sea level during 2010-2011 growing season. The climate of the region is classified as warm and semiarid. The soil type was sandy loam with pH 7.8 and a 0.52% average organic matter. Soil sample analysis indicated that at the depth of the 0 - 30 cm soil layers contained 0.039% nitrogen, 13 mg kg^{-1} phosphorus and 151 mg kg^{-1} potassium.

The experimental design was split plot based on randomized complete block with four replications. The main plots consisted of N fertilizer rates (i.e. 0, 50, 100 and 150 kg N ha^{-1}) that used as NO_3 in form of urea fertilizer. The sub-plots consisted of five green manure crops and the control (without green manure). Green manure crops were millet (*Pennisetum* sp.), sesbania (*Sesbania* sp.), amaranth (*Amaranthus* sp.), cowpea (*Vigna unguiculata* L.) and mung bean (*Vigna radiate* L.). The plots of green manure were established on 6 Sep. 2010 and incorporated to the soil on 7 Oct. 2010. Then wheat (cv. Chamran) seeded at a rate of 180 $kg.ha^{-1}$ on 16 Nov. 2010 and harvested on 21 Apr. 2011. Each main plot size was 24 m^2 (8x3 m) that divided to four sub-plots consisted of 7 rows of wheat plants, 3 m in length, interrow spacing was 20 cm and interplant spacing was 3 cm.

Plant samples were taken at anthesis and maturity. After each harvest, plants were separated into leaf plus culm and chaff at anthesis, and also grain at maturity. These segments were immediately dried in a dry oven at 70°C for 48 h and weighted. Grain yield was determined by harvesting a 2 m^2 area from each plot. All dry vegetative samples and also grains were first ground and then plant N concentration was determined by standard macro-Kjeldahl procedure. N content was calculated by multiplying the N concentration by dry weight. Moreover, the following parameters, related to dry matter and N accumulation and translocation within the wheat plant during grain filling, were calculated according to Arduini et al. (2006) and Masoni et al. (2007), as follow:

1. Dry matter translocation (Mg ha^{-1}) = Dry matter at anthesis – [(leaf + culm) + chaff] dry matter at maturity.

2. Dry matter translocation efficiency (%) = (Dry matter translocation / Dry matter at anthesis) ? 100.

3. Contribution of pre-anthesis assimilates to grain (%) = (Dry matter translocation / grain yield) ? 100.

4. Harvest index (HI) = Grain yield / total aboveground biomass at maturity.

5. Nitrogen translocation (kg ha^{-1}) = N content at anthesis – [(leaf + culm) + chaff] N content at maturity.

6. Nitrogen translocation efficiency (%) = (N translocation / N content at anthesis) x 100.

7. Nitrogen lost (–) or gained (kg ha^{-1}) = N content at maturity – N content at anthesis.

8. Nitrogen at anthesis lost or gained (%) = (N lost or gained / N content at anthesis) x 100.

9. Nitrogen harvest index (NHI) = Grain N / total N content of aboveground parts at maturity.

Data were statistically analyzed according to ANOVA, in order to test the main effects of nitrogen rate, green manure crops and their interactions with using of SAS software. Differences between means were compared using LSD test ($p<0.05$).

Results and Disscussion

Dry matter translocation

Wheat plants as affected by different green manure crops markedly showed differences with respect to the changes in vegetative dry matter at anthesis and maturity. But, showed non-significantly impact on dry matter translocation efficiency (Figures 1b, 2b, 3b and Table 1). Great dry matter at anthesis resulted in a low proportion of mobilized dry matter. For instance, between different green manure crops, cowpea showed the lower dry matter translocation efficiency (18.7 %) than other green manure crops when the dry matter at anthesis was higher (17.2 mg ha^{-1}). Obviously, this result was due to components of legume and non-legume green manures such as carbon to nitrogen (C/N), and lignin to nitrogen (L/N) ratios. Dry matter translocation efficiency also was affected by nitrogen fertilizer application. However, dry matter translocation efficiency was greater in 0 kg N ha^{-1} (control) than other N supplies (Table 1). Leguminous plants form symbiotic associations with rhizobium bacteria in order to fix N2.This fact causes that the green manures, which their principal components are leguminous plant debris, supply to the soil important amounts of N in relation to the green manures obtained from non-leguminous plants (Tejada et al., 2008). The contribution of pre-anthesis assimilates to grain ranged from 20 - 71.1 of grain dry weight and significantly differed just among green manure crops (Table 1). Green manure crops that received low N application showed higher contribution of pre-anthesis assimilates in wheat than those that receiving high N fertilizer. With N applications, green manure crops had more supply of N during the post-anthesis stage. This condition is presumably conductive to higher rates of photosynthesis and, in turn, to a higher supply of assimilates for grain fill, thus reducing the need for translocation of pre-anthesis assimilates. Alvaro et al. (2008) reported that, the amount of dry matter remobilization, dry matter remobilization efficiency and contribution of pre-anthesis assimilates to grain from the main stem structures to growing grains increased significantly in Italian wheat cultivars. But, application of green manure together nitrogen fertilizer, carbon and nitrogen ratio in soil will balance and plants can uptake nitrogen requirement and other nutrients from soil. Thus, plants can growth and have suitable in condition (Mosavi et al., 2009).

Positive and significant correlation was observed between harvest index (HI) and dry matter translocation efficiency (0.45**) but not for the contribution of pre-anthesis assimilates and harvest index (-0.01ns) (Table 3). No significant correlation was found between HI and grain yield (Table 3). But, the harvest index values were significantly different between various green manure crops and N rates. Similar result was reported by Jiang et al. (2008) when N application significantly affected the harvest index.

In addition, differences in dry matter at anthesis and maturity were observed among green manure crops (Figure 1b, 2b and 3b). The application of all N fertilizers significantly increased aboveground dry matter at both anthesis and maturity which resulted in greater grain yield than unfertilized plot (Figure 1a, 2a, 3a and Table 2). In addition, grain yield was positively correlated to total dry matter at anthesis and maturity 0.75** and 0.76**, respectively (Table 3). Moreover, a decrease in vegetative dry matter between anthesis and maturity was observed both in leaf + culm and in chaff when the dry matter at anthesis was higher (Figure 1a and 2a). In warm type climate, the weather after anthesis is usually hot and dry. The rate of photosynthesis declines at temperatures higher than 30°C. the effect of temperature on current assimilation during

Table 1
Dry matter translocation efficiency, Contribution of pre-anthesis assimilates to grain, N translocation efficiency and N harvest index as affected by different N fertilizer rate and green manure crops

Treatment	DMTE‡ %	CPA§	HI†	NTE*	NHI¶
Nitrogen (N)					
N_0	26.9 a	51.7 a	42.1 a	72.2 b	75.1 bc
N_{50}	21.3 b	35.4 b	43.9 a	76.8 a	80 a
N_{100}	18.3 bc	34.8 b	40.2 bc	75.8 a	76.5 b
N_{150}	16.7 c	32.7 b	38.5 c	75.6 a	74.2 c
Green manure(GM)					
Control	24.1 a	44.3 a	42.3 ab	73.7 b	73.6 b
Millet	20.4 ab	32.8 b	44 a	74.5 ab	76.9 a
Sesbania	19.1 b	40 ab	39 b	73.9 b	76.7 ab
Amaranth	22.5 ab	43.5 a	41.7 ab	76.6 a	78.2 a
Cowpea	18.7 b	33.9 b	40.1 b	75.6 a	77.9 a
Mung bean	19.5 b	37.5 ab	39.8 b	76.5 a	75.5 ab
N × GM					
N_0 × Control	34.7 a	66.8 ab	44.7 a-d	75 b-f	75 b-g
N_0 × Millet	26.2 bc	48.4 c-e	42.4 b-e	71.6 d-g	75.4 b-g
N_0 × Sesbania	22.3 b-f	43.5 c-g	39.9 b-g	66.4 g	74.2 c-g
N_0 × Amaranth	34.2 a	71.1 a	42.8 b-e	74.5 b-f	77.2 a-f
N_0 × Cowpea	21.1 c-g	30.6 c-g	45.9 a-c	69.3 e-g	77.7 a-e
N_0 × Mung bean	22.7 b-f	49.9 b-d	36.9 e-g	76.3 a-e	71.1 gh
N_{50} × Control	23.8 b-d	36.3 d-i	46.3 ab	74.7 b-f	79.3 a-d
N_{50} × Millet	29.4 ab	40.5 c-h	50.9 a	80.1 a-c	81 ab
N_{50} × Sesbania	12.9 h	21.3 i	41 b-f	74.3 b-f	80.8 ab
N_{50} × Amaranth	19 c-h	36.6 d-i	41.5 b-f	78.5 a-d	78.4 a-e
N_{50} × Cowpea	24.5 bc	45.3 c-f	42 b-e	78.2 a-d	83.2 a
N_{50} × Mung bean	18.5 c-h	32.2 d-i	41.6 b-f	75.6 a-f	77.5 a-f
N_{100} × Control	22.9 b-e	40.9 d-f	42.9 b-e	75.7 a-f	73.9 d-g
N_{100} × Millet	12.6 h	20 i	41.9 b-f	68.7 fg	73.7 d-g
N_{100} × Sesbania	25 bc	55.2 a-c	38.2 d-g	75.5 a-f	75.8 b-g
N_{100} × Amaranth	11.6 h	20.3 i	39.5 c-g	72.9 c-g	76.3 b-g
N_{100} × Cowpea	16.2 d-h	31 e-i	38.3 d-g	79.5 a-c	79.2 a-d
N_{100} × Mung bean	21.7 b-f	41.6 c-g	40.1 b-g	82.6 a	80 a-c
N_{150} × Control	14.9 f-h	33.3 d-i	35.4 fg	69.5 e-g	66.1 h
N_{150} × Millet	13.6 gh	22.5 hi	40.9 b-f	77.6 a-d	77.6 a-f
N_{150} × Sesbania	18.7 c-h	39.8 c-h	36.8 e-g	79.3 a-c	76.1 b-g
N_{150} × Amaranth	25.2 bc	46 c-f	42.9 b-e	80.5 ab	80.8 ab
N_{150} × Cowpea	12.9 h	28.8 f-i	34.2 g	75.3 a-f	71.57 f-h
N_{150} × Mung bean	15.1 e-h	26.1 g-i	40.6 b-g	71.5 d-g	73.23 e-g

‡ Dry matter translocation efficiency, § Contribution of pre-anthesis assimilates to grain, † Harvest Index
* Nitrogen translocation efficiency, ¶ Nitrogen harvest index.

grain filling and remobilization of pre-anthesis reserves can vary with N availability, as differences in plant size due to N fertilization can affect the amount of accumulated and remobilized reserves within the plant (Papakosta and Gagianas, 1991). Green manure C/N ratios varied from 20 to 37, depending on the species. Green manures

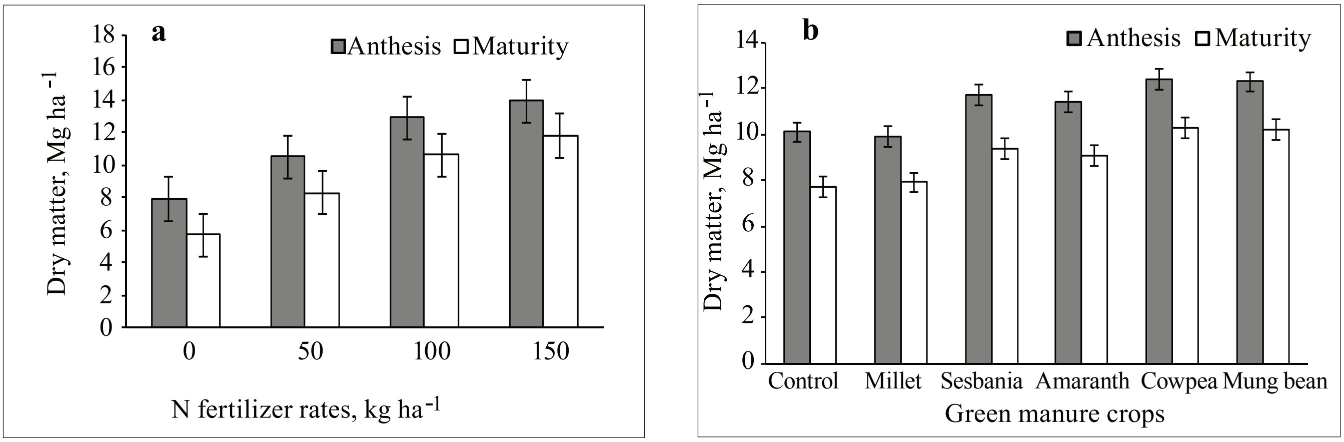

Fig. 1. Dry matter at anthesis and maturity in leaf+culm as affected by nitrogen rates (a) and green manure crops (b)

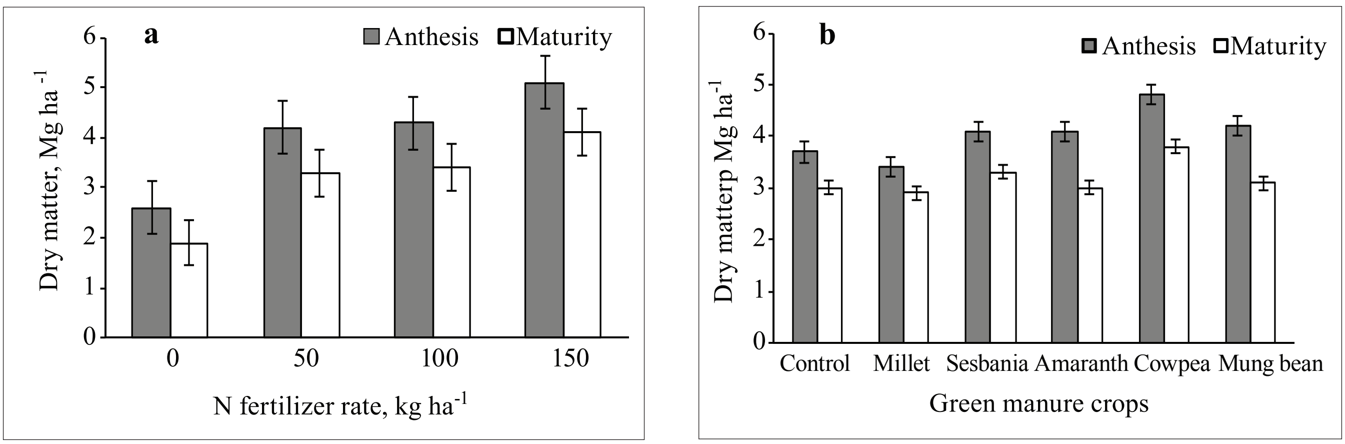

Fig. 2. Dry matter at anthesis and maturity in chaff as affected by nitrogen rates (a) and green manure crops (b)

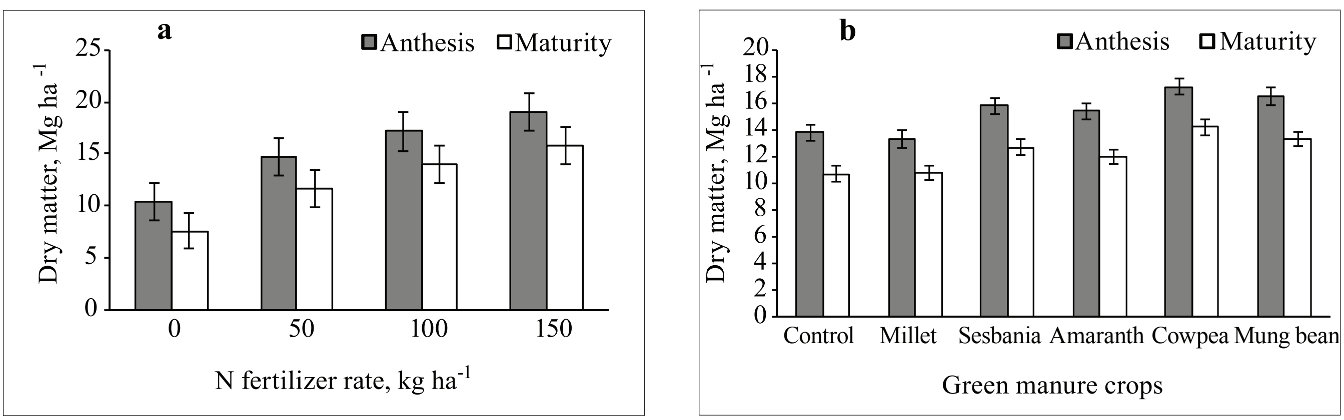

Fig. 3. Dry matter at anthesis and maturity in total vegetative parts as affected by nitrogen rates (a) and green manure crops (b)

with lower C/N ratios decompose rapidly and have a rapid effect on soil physical properties and on biological activity (Mosavi et al., 2009) and therefore could increase subsequent crop yields and nutrition. Also, Dordas et al. (2009) reported that dry matter accumulation and partitioning into different plant parts were different due to fertilization treatments. While, aboveground biomass increased at post anthesis in all fertilization treatments. These authors suggested that dry matter production was directly related to N supply and when this amount of N abated it causes to inhibit dry matter production, especially in leaves. This affects the production of photo-assimilates and the distribution of assimilates to the reproductive organs. Tahir and Nakata (2005) reported that, when reserved material deposited in vegetative plant parts at the pre–anthesis it may buffer grain yield when conditions become adverse to photosynthesis and mineral uptake during grain filling. Decrease in dry matter between anthesis and maturity

Table 2
Dry matter, Nitrogen concentration and N content in reproductive parts as affected by different N fertilizer rate and green manure crops

Treatments	Grain yield	NUE	UPE	UTE	NRI	NBI
	ton ha^{-1}	kg kg^{-1}				
Nitrogen (N)						
N_0	3.25 b ¶	32.54 a	0.84 a	39.85 a	-	-
N_{50}	5.7 a	30.43 a	0.78 ab	39.29 a	0.25 c	2.35 a
N_{100}	6:00 AM	22.84 b	0.73 b	32.02 b	0.40 b	1.30 b
N_{150}	6.15 a	20.22 b	0.70 b	29.33 b	0.50 a	1.19 b
Plant × Weed density						
D_1W_0	5.74 a δ	24.1 b	0.87 a	27.92 b	0.26 b	1.53 a
D_1W_1	4.96 b	23.83 b	0.75 bc	31.74 b	0.27 b	1.16 b
D_2W_0	5.53 ab	31.52 a	0.77 b	41.5 a	0.31 a	1.20 b
D_2W_1	4.88 b	26.58 b	0.68 c	39.33 a	0.31 a	0.95 b
Interactions						
$N_0D_1W_0$	3.9 de	25.80 c-f	0.91 a	28.52 fg	-	-
$N_0D_1W_1$	2.81 e	32.67 a-c	0.8 a-e	41.3 a-e	-	-
$N_0D_2W_0$	3.05 e	39.26 a	0.88 ab	45.33 a-c	-	-
$N_0D_2W_1$	3.25 e	32.42 a-c	0.78 b-e	42 a-d	-	-
$N_{50}D_1W_0$	6.53 bc	28.95 b-e	0.95 a	30.18 e-g	0.22 e	2.9 a
$N_{50}D_1W_1$	5.13 cd	24.09 c-f	0.83 a-d	28.17 fg	0.23 e	2.05 c
$N_{50}D_2W_0$	6.47 bc	36.22 ab	0.69 c-f	52.6 a	0.28 e	2.53 b
$N_{50}D_2W_1$	5.89 bc	32.48 a-c	0.68 c-f	48.02 ab	0.28 e	2.03 cd
$N_{100}D_1W_0$	7.15 a	19.36 d-f	0.8 a-e	25.75 g	0.36 d	1.53 c-e
$N_{100}D_1W_1$	5.1 cd	19.02 f	0.7 b-f	27.82 fg	0.38 cd	1.34 ef
$N_{100}D_2W_0$	5.47 cd	30.10 bc	0.86 a-c	36.11 c-g	0.44 b	1.42 d-f
$N_{100}D_2W_1$	5.33 cd	22.87 d-f	0.6 f	38.37 b-f	0.43 bc	0.89 f
$N_{150}D_1W_0$	7.32 a	22.27 f	0.85 a-c	27.24 fg	0.46 b	1.79 c-e
$N_{150}D_1W_1$	6.35 bc	19.52 f	0.67 d-f	29.23 fg	0.47 b	1.25 ef
$N_{150}D_2W_0$	5.69 bc	20.52 ef	0.65 d-f	31.94 d-g	0.54 a	0.85 f
$N_{150}D_2W_1$	5.24 cd	18.56 f	0.64 ef	28.92 fg	0.53 a	0.88 f

δ D_1: 180 kg ha^{-1} (optimum wheat density), D_2: 300 kg ha^{-1} (high wheat density), W_0: control (absent weed), W_1: weed present (30 weed.m^{-2}).
¶ In each section, means followed by the same letter within columns are not significantly different ($p < 0.05$) according to LSD test.

was reported in wheat, and it varied greatly with environmental factors (Cartelle et al., 2006). Moreover, carbon reserves in stem and leaves can contribute to grain filling in some plants such as sunflower and wheat (Sadras et al., 1993). In other hand, the harvest index is an indication of how the vegetative mass is allocated to seed at maturity.

Nitrogen accumulation and remobilization

At the maturity stage, with increase nitrogen application the N content was increased more in grain than vegetative parts (Table 2, Figure 5a). Nitrogen content of vegetative parts of wheat plants (leaf + culm + chaff) at maturity was highly positively correlated (0.82**) with N content at anthesis (Table 3). Unfertilized plants remobilized about 6% less N than unfertilized plants (Table 1). In fact, all N contents and N concentrations in vegetative parts and grain yield of wheat were increased with the addition of N rates but, no significantly differences were found for nitrogen translocation efficiency (Figures 4a and 5a, Tables 1 and 2). Different green manure crops had no significantly effect

Table 3
Simple correlation coefficient between various dry matter and nitrogen parameters

Treatments	NHI	NRE	NHE	NFUE
	%		kg kg^{-1}	
Nitrogen (N)				
N_0	77.04 a	77.21 a ¶	0.65 a	-
N_{50}	71.31 ab	71.44 ab	0.58 ab	120.09 a
N_{100}	69.46 b	70.70 ab	0.54 ab	56.99 b
N_{150}	68.87 b	68.61 b	0.51 b	41.00 c
Plant × Weed density				
D_1W_0	73.68 a	73.55 a δ	0.71 a	58.50 a
D_1W_1	68.47 a	67.10 a	0.51 b	48.99 b
D_2W_0	73.37 a	75.35 a	0.59 b	59.07 a
D_2W_1	71.16 a	71.96 a	0.48 b	51.51 ab
Interactions				
$N_0D_1W_0$	77.00 a-c	73.63 a	0.81 ab	-
$N_0D_1W_1$	73.96 a-d	73.47 a	0.48 de	-
$N_0D_2W_0$	76.56 a-c	80.82 a	0.77 a-c	-
$N_0D_2W_1$	80.64 a	80.93 a	0.56 c-e	-
$N_{50}D_1W_0$	74.31a-d	70.81 ab	0.82 a	130.54 a
$N_{50}D_1W_1$	59.92 e	69.50 ab	0.59 b-e	102.63 b
$N_{50}D_2W_0$	79.41 ab	72.81 a	0.45 de	129.32 a
$N_{50}D_2W_1$	71.58 a-e	72.64 a	0.47 de	117.87 ab
$N_{100}D_1W_0$	72.85 a-d	71.69 a	0.66 a-d	54.67 cd
$N_{100}D_1W_1$	70.53 a-e	71.93 a	0.49 de	50.99 d-f
$N_{100}D_2W_0$	65.87 c-e	70.75 ab	0.50 de	69.03 c
$N_{100}D_2W_1$	68.60 b-e	68.41 ab	0.52 de	53.26 c-e
$N_{150}D_1W_0$	69.36 a-e	78.08 a	0.55 c-e	48.81 d-f
$N_{150}D_1W_1$	69.48 a-e	53.51 b	0.49 de	42.35 d-f
$N_{150}D_2W_0$	72.83 a-d	77.00 a	0.63 a-d	37.94 ef
$N_{150}D_2W_1$	63.83 de	65.85 ab	0.38 e	34.90 f

δ D_1: 180 kg ha^{-1} (optimum wheat density), D_2: 300 kg ha^{-1} (high wheat density), W_0: control (absent weed), W_1: weed present (30 weed.m^{-2}).
¶ In each section, means followed by the same letter within columns are not significantly different ($p < 0.05$) according to LSD test.

on wheat vegetative parts at maturity but, significantly affected on grain N content (Figure 3b and Table 2). Our result showed significant differences for N translocation efficiency among green manure crops but, no differences among N application rates. N accumulation and partitioning were affected by level of N availability and the growing condition, and these increased compared with the controls. N content decreased from anthesis to maturity in vegetative tissues (leaves + stems). This indicated remobilization of N from vegetative tissues to the seed. Post-anthesis N accumulation and seed N content were increased with N fertilization. (Dordas and Sioulas, 2009). Also, one explanation for differences in remobilization efficiency is that during grain filling period, the plant retains an amount of N at anthesis that is essential for survival and various biological functions, while the remainder is available for remobilization. It appears that N retention depends on cultivars and the prevailing growth conditions, although, genetic variability in nitrogen remobilization has been reported (Bahrani et al., 2011).

The N content at anthesis in total vegetative parts (leaf + culm and chaff) was higher in plants receiving N fertilizer than in control and increased with the addition of N supplement (Figure 5a). Green manure crops were differed in their ability to accumulate N in vegetative parts of wheat crops prior to anthesis (Figure 5b). Therefore, it seems that plant N content was associated with both variations in dry matter and N concentration (Figure 1 and 4). Green manure had a high N contribution to wheat nutrition required for maximum wheat yield, and this effect was due to N input in soil by green manures. In fact, synchronization between N mineralization and N uptake appears to be an important factor controlling N availability to subsequent crops. For wheat with a short

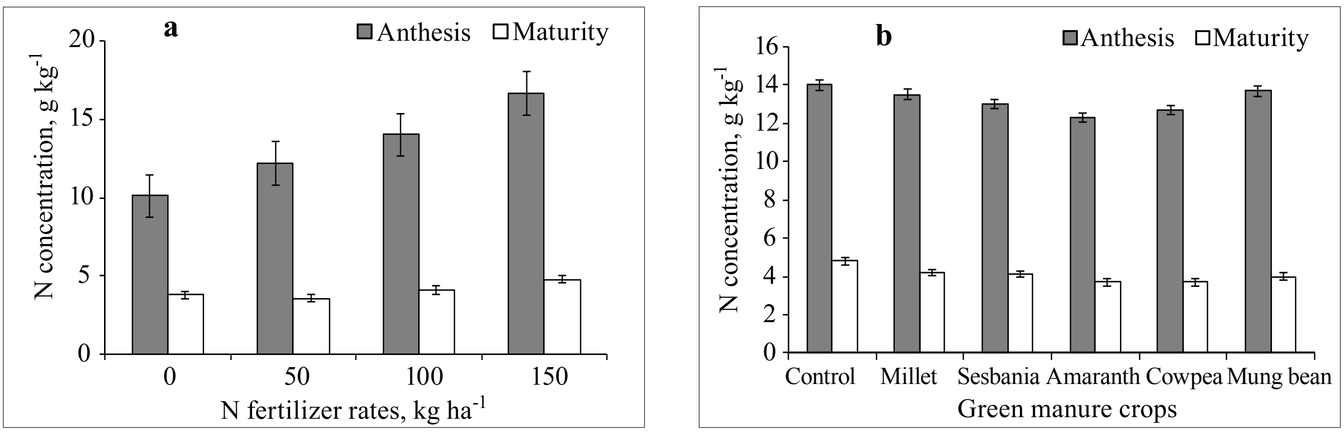

Fig. 4. Nitrogen concentration at anthesis and maturity in total vegetative parts as affected by nitrogen rates (a) and green manure crops (b)

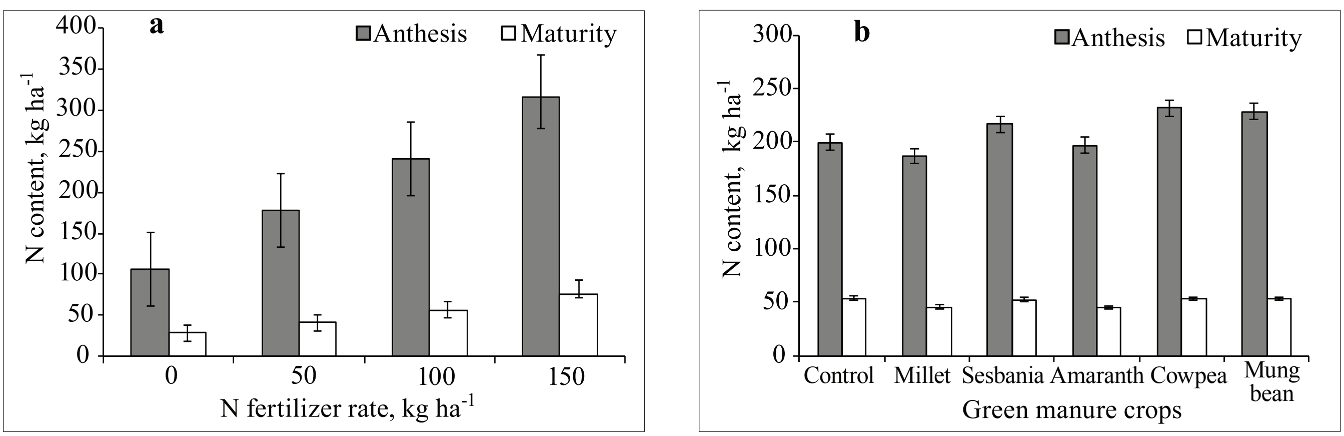

Fig. 5. Nitrogen content at anthesis and maturity in total vegetative parts as affected by nitrogen rates (a) and green manure crops (b)

growing season, green manure incorporation should be made in the fall to allow residue decomposition and N availability. Przulj and Momcilovic (2001) found a variation in N accumulation and remobilization to the kernel of the spring barley. Also, N remobilization, N remobilization efficiency and nitrogen harvest index were mainly influenced by the barley cultivars. Therefore they suggested that, differences among cultivars for N remobilization were related to the status of dry matter and N accumulation at anthesis. In our study, in average two non-legume green manure crops (e.g. amaranth and millet) had the higher value of nitrogen remobilization efficiency probably due to higher dry matter translocation efficiency and also higher nitrogen harvest index (Table 1). Although, the highest nitrogen translocation efficiency (76.5%) was belonged to mung bean (legume green manure crops). Badaruddin and Meyer (1990) showed that, the increases in wheat yields and N uptake were highest for millet and colza (non-legume green manure crops) and could be related to their highest biomass and N content inputs by these crops. Although, most studies on green manure are related to leguminous crops, which present a high potential to atmospheric N fixation and availability to subsequent crops which, efficiency and utilization of N were greater following these legume green manure crops than following either fallow or wheat. Wall and Kanemasu (1990) reported that, the wheat plants with low crop densities had lowlight interception efficiency and net dry matter productivity. In addition, the higher remobilization in this was probably linked to the higher dry matter of the crop at heading that represents the potential source for remobilization (Przulj and Momcilovic, 2001). Grain yield and grain N content at maturity increased with the addition of N fertilizer from N0 to N150 by 60 and 59.9%, respectively (Table 2). N150 had shown the highest effect for these parameters, for all green manure crops. In addition, between green manure crops, cowpea produced the highest grain yield (9.1 mg ha^{-1}) and grain N content (185.3 kg ha^{-1}) in wheat crops (Table 2). Also, grain N content was significantly correlated with nitrogen harvest index, but not significant correlation with nitrogen translocation efficiency (Table 3). Nitrogen absorption by cereals is thought to take place mainly before anthesis. Thus, over 80% of the final N content is present in the plant at anthesis and the N accumulated before anthesis in winter wheat can count for as much as 75–90% of the final N content of the grains (Heitholt et al., 1990). It is reported that, in wheat the extent of N accumulation is determined by the relationships between the capacity of the plants to absorb and remobilized N (Fageria and Baligar, 2005). Also, Cox et al. (1986) showed that higher levels of nitrogen fertilization before flowering lead to a decrease in nitrogen remobilization efficiency and also renders nitrogen remobilization. Moreover, Barbottin et al. (2005) reported that, the effect of the environment on the relationship between nitrogen uptake at flowering and nitrogen remobilization depended on nitrogen uptake during grain-filling period.

Although, N fertilizer increased N content at anthesis (Figure 4a). But, the nitrogen harvest index (NHI) was not significantly affected by N application between green manure crops (Table 1). Among all green manure crops, amaranth showed the highest wheat nitrogen harvest index which is capable to effect on succeeding wheat plants to preserve great N translocation efficiency and dry matter translocation efficiency (Table 1). Similar result was reported by Loffler et al. (1985) in which increases in nitrogen harvest index or total N at maturity may increase grain protein concentration without reducing yield. They suggested that nitrogen harvest index can be used as a selection criterion to improve grain yield while maintaining the grain protein concentration. Although, H?tensteiner and Feller (2002) concluded from the data of other studies that this index was consistent for rice, maize and wheat over a wide range on N availability.

When the N content of aboveground plant parts at anthesis and maturity are compared, it indicated that both gains and losses were observed for wheat crops (Table 4).

The nitrogen losses ranged from 2.4–59.2 kg N ha^{-1}. Nitrogen gains ranged from 0.5–59.3 kg N ha^{-1}. Nitrogen lost or gained was related to wheat grain yield development and this alternation was varied among green manure crops. But, N lost or gained was related to nitrogen content at anthesis and grain yield development and these alterations were varied among green manure crops (Table 4). Our study indicated that, N lost depends primarily on the N content at anthesis. The highest wheat N content at anthesis (375.5 kg ha^{-1}) show the high value of N loss (-59.2 kg ha^{-1}). Also, in all N rates, millet had highest N gains. Talgre et al. (2009) reported that, when growing spring cereals as preceding crops, it is practical to apply the green manure crop in late autumn or spring in order to minimize nitrogen loss. The risk of N loss depends on the N content of green manure crops. It is advisable to plough green manure fallows grown on cereal fields or having high N content as the last ones in autumn (Kaushal et al, 2010). Harper et al. (1987) found that 11% of the potential N available for redistribution was lost as volatile NH3. It is probable when N decline in plant tops can cause to

Table 4
N lost (–) or gained, N content at anthesis, gain yield and percentage of N at anthesis lost (–) or gained in wheat plants as affected by different N fertilizer rate and green manure crops

	NUE	UPE	UTE	NRI	NBI	NHI	NRE	NHE	NFUE	Grain yield
NUE	1									
UPE	0.28 *	1								
UTE	0.72 **	-0.43 *	1							
NRI	-0.08NS	0.14NS	-0.18NS	1						
NBI	0.43 **	0.65 **	-0.12NS	0.34 *	1					
NHI	0.3 *	0.21NS	0.12 NS	-0.36 *	0.01 ns	1				
NRE	0.21NS	-0.06NS	0.23NS	-0.16NS	-0.11NS	0.8NS	1			
NHE	0.36 *	0.94 **	-0.32 *	0.01NS	0.58 **	0.52 **	0.23 NS	1		
NFUE	0.55 **	0.42 **	0.15NS	0.31 *	0.92 **	-0.11NS	-0.18NS	0.34 *	1	
Grain yield	0.52 **	0.39 **	0.2NS	0.66 **	0.61 **	-0.08NS	-0.16NS	0.32 *	0.64 **	1

NUE = N use efficiency, UPE = N uptake efficiency, UTE = N utilization efficiency, NRI = N reliance index, NBI = N balance index, NHI = N harvest index, NRE = N remobilization efficiency, NHE = N harvest efficiency, NFUE = N fertilizer utilization efficiency.
** (P<0.01), * (P<0.05), NS: non-significant ($P \geq 0.05$).

cease plant carbohydrates, a situation which limit capacity of inflorescence to store N. Przulj and Momcilovic (2001) reported that in barley cultivars N losses mainly depended on plant N content at anthesis, exactly, when plant N content was over 150 kg ha^{-1}.They also suggested that, cultivars with a high capacity for N accumulation at pre-anthesis, high remobilization efficiency and high nitrogen harvest index could be used in the development of cultivars with the desired N balance.

Conclusion

Dry matter accumulation and N content and concentration were always greater at anthesis than maturity for wheat plants after all green manure crops and also in all N rates. Lower amounts of dry matter at anthesis resulted in agreater dry matter translocation efficiency. But, this parameter was decreased with increase in N application. Nitrogen harvest index and harvest index had similar trends as the same as dry matter translocation efficiency. But, both were highest in the non-legume green manures than legume green manures. At the highest N application rates dry matter translocation efficiency, contribution of pre-anthesis assimilates to grain, nitrogen translocation efficiency, harvest index and nitrogen harvest index were greatest in amaranth (non-legume) green manure crops. But, at the optimum and lower N application rates (100 and 50 kg N ha^{-1}) this parameters were greatest in all legume green manure crops. In addition, greatest N losses also occurred at the highest N rates. Consequently, high amounts of N accumulated at anthesis led to worst N loss at maturity.

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