

Response of wheat to mineral nitrogen fertilizer and biofertilizer (*Azotobacter* sp. and *Azospirillum* sp.) inoculation under different levels of weed interference

Ali Namvar^{*},

Teymur Khandan

Young Researchers Club,
Ardabil Branch,
Islamic Azad University,
Ardabil, Iran

It is important to develop integrated fertilization strategies for crop production that enhance the competitive ability of the crop, minimize weed competition, and reduce the risk of nonpoint source pollution from nitrogen. In order to study the effects of mineral nitrogen fertilization and biofertilizer inoculation on grain yield, yield components and protein content of wheat (*Triticum aestivum* L.) under different levels of weed interference, a field experiment in Factorial scheme based on Randomized Complete Block design was conducted in three replications. Experimental factors were: (i) Four levels of chemical nitrogen fertilizer (0, 100, 150 and 200 kg N ha⁻¹), (ii) Two levels of biofertilizer (with and without inoculation) containing *Azotobacter* sp. and *Azospirillum* sp. and (iii) Two levels of weed interference (weedy check and weed free). Wheat yield, yield components and protein content of grains had a strong association with the N fertilization, biofertilizer inoculation and weed interference. Higher rates of N fertilization and biofertilizer (*Azotobacter* sp. and *Azospirillum* sp.) inoculation increased plant height, spike number per unit of area, grains number per spike, 1 000-grains weight, grain yield, biological yield and grain protein content while weeds interference decreased significantly all these traits except plant height. Application of 150 kg N ha⁻¹ was statistically in par with 200 kg N ha⁻¹ in the most of the studied traits. Moreover, our results showed that manual hoeing prevents weeds from being a limiting factor for crop productivity in wheat. It seems that moderate N rate (about 150 kg N ha⁻¹) can be beneficial to improve growth, development and total yield of inoculated wheat. Thus it is suggested to use a combination of organic and inorganic fertilizers to achieve the highest yield without negative effect on grain quality that will lead to environmental conservation.

Key words: biofertilizer, grain yield, nitrogen, protein content, weed interference, wheat, yield components

INTRODUCTION

Wheat (*Triticum aestivum* L.) is an important staple crop around the world. Its importance has risen even more due to frequently experienced food shortages and its role in world trade. Wheat ranks first among the cereal crops, accounting for 30% of all cereal food worldwide and major food for over one third of world people that provides about

20% of the total food calories directly or indirectly for the human race. Increasing wheat production to meet higher demands by growing populations is still a challenge in many countries (Sary et al., 2009; Abedi et al., 2012; Campuzano et al., 2012).

Weeds are one of the greatest threats to agricultural crop production. They use the soil fertility, available moisture, nutrients, providing shelter for insect-pest and compete for space and sunlight with crop plants which causes yield reduction. Apart

^{*} Corresponding author. E-mail: Namvar_a60@yahoo.com

from quantitative effects on yield weeds deteriorate the quality of produce through the physical presence of their seeds and debris (Blackshaw et al., 2005; Kolb, Gallandt, 2012; Scursoni et al., 2012). Yield losses and harvest problems caused by weeds in wheat vary depending on weed species, weed population, time of weed emergence, growing conditions, and status of the wheat crop (Petit et al., 2011; Kolb, Gallandt, 2012). The use of herbicides for weed control, however, is too uneconomical in addition to resulting in serious ecological and environmental problems such as increase in herbicide resistance in the weeds, ground water contamination and environmental pollution (Riaz et al., 2006; Petit et al., 2011; Armengot et al., 2013). One of the suggested ways to control weeds in cereals is to improve the ability of the crop itself to suppress weeds and fertilization management is an important factor in optimizing crop production and increasing crop competition ability for weed management (Kolb, Gallandt, 2012). Reduction of yield and its components with weeds infestation is documented by many researchers (Blackshaw et al., 2005; Khan et al., 2007; Azeez, 2009; Scursoni et al., 2012). Sary et al. (2009) reported that weeds control had superiority effects on wheat tiller, spike and grain number per unit of area, 1 000-grains weight, grain yield, harvest index and protein content.

Maintaining soil fertility and use of plant nutrients in sufficient and balanced amounts is one of the key factors in increasing crop yield (Diacono et al., 2013). Nitrogen (N) is the most important nutrient supplied to most non-legume crops, including wheat. The most important role of N in the plant is its presence in the structure of protein and nucleic acids, which are the most important building and information substances of every cell. In addition, N is also found in chlorophyll that enables the plant to transfer energy from sunlight by photosynthesis. Thus, N supply to the plant will influence the amount of protein, amino acids, protoplasm and chlorophyll formed. Moreover, it influences the cell size, leaf area and photosynthetic activity (Azeez, 2009; Namvar et al., 2012; Daneshmand et al., 2012; Piccinin et al., 2013; Diacono et al., 2013). Therefore, adequate supply of N is necessary to achieve high yield potential in crops. N fertilizer is known to affect the number of tillers m^{-2} , number of grains spike $^{-1}$, spike

length and weight, 1 000-grain weight and grain yield of wheat (Kizilkaya, 2008; Kandil et al., 2011; Wortman et al., 2011; Campuzano et al., 2012; Liu, Shi, 2013). Abedi et al. (2010) investigated wheat response to different levels of nitrogen fertilizer (0, 80, 160 and 240 kg N ha^{-1}) and stated that the highest wheat grain yield (5844.59 kg ha^{-1}) was achieved when the plants were fertilized with 160 kg N ha^{-1} .

Increasing and extending the role of biofertilizers can reduce the need for chemical fertilizers and decrease adverse environmental effects. They can play a significant role in fixing atmospheric N and production of plant growth promoting substances. Therefore, in the development and implementation of sustainable agricultural techniques, biofertilization has great importance in alleviating environmental pollution and deterioration of nature (Saini et al., 2004; Namvar et al., 2012; Rana et al., 2012). *Azotobacter* sp. and *Azospirillum* sp. are used as biofertilizers in the cultivation of many agricultural crops. The estimated contribution of these free-living N fixing prokaryotes to the N input of soil ranges from 0–60 kg/ha per year (Vessey, 2003). Existence of microbial communities like *Azotobacter* sp. and *Azospirillum* sp. in the rhizosphere promotes the growth of the plant through the cycling and availability of nutrients, increasing the health of roots during the growth stage by competing with root pathogens and increasing the absorption of nutrients and water (Vessey, 2003; Zorita, Canigia, 2009; Daneshmand et al., 2012). Kandil et al. (2011) studied the effects of inoculation with *Azotobacter* sp. and *Azospirillum* sp. on wheat and observed that inoculated wheat plants gave higher plant height, spike per unit of area, grains per spike, grain weight, biological yield, grain yield and straw yield compared to non-inoculated cultivars. Zorita and Canigia (2009) found that seed inoculation can increase the number of harvested grains by 6.1% and grain yield by 260 kg ha^{-1} (8.0%) in wheat. Similar results were reported by Kizilkaya (2008); Sary et al., (2009) and Daneshmand et al., (2012). Some of investigations have suggested that integrated nutrient management strategies involving inoculation of seeds with *Azotobacter* sp. and *Azospirillum* sp. in combination with chemical fertilizers result in improving both growth and yield of crops, i. e. wheat (Saini et al., 2004; Piccinin et al., 2013).

It is important to develop integrated fertilization strategies for crop production that enhance the competitive ability of the crop, minimize weed competition, and reduce the risk of nonpoint source pollution from nitrogen. Moreover, it seems that there is little investigation on combined effects of organic and inorganic nitrogen fertilization under different rates of weed interference in some crops such as wheat. Hence, considering the above facts, the present study was undertaken to study the effects of various rates of mineral nitrogen fertilization and biofertilizer (*Azotobacter* sp. and *Azospirillum* sp.) inoculation on yield, its attributes and protein content of wheat under different levels of weed interference.

MATERIALS AND METHODS

In order to study the effects of chemical nitrogen fertilization and biofertilizer inoculation on grain yield, yield components and protein content of wheat (*Triticum aestivum* L.) under different levels of weed interference, a field experiment in Factorial scheme based on Randomized Complete Block design was conducted in three replications. Experimental factors were: (i) Four levels of chemical nitrogen fertilizer (0, 100, 150 and 200 kg N ha⁻¹), (ii) Two levels of biofertilizer (with and without inoculation) containing of *Azotobacter* sp. and *Azospirillum* sp. and (iii) Two levels of weed interference (weedy check and weed free). In each level, chemical nitrogen fertilizer (used in the form of urea) was divided into two equal parts; the first part of the N was disseminated by hand and incorporated immediately during planting time, the second part was used during the stem elongation stage. Nitroxin was used as a biological fertilizer (containing *Azotobacter* sp. and *Azospirillum* sp., 10⁸ cfu mL⁻¹) in the amount of one litre per 30 kg of seed. In weed free treatment, the first manual hoeing was done 25 days after sowing while the remaining three manual hoeings were done at 30 days interval to keep the crop weed free for the entire growth period.

The area is located at latitude 37°56'N and longitude 47°35'E at an altitude of 1 350 m above the mean sea level. Climatically, the area is located in the semi arid temperate zone with cold winter and hot summer. Annual average rainfall was about 350 mm and most rainfall concentrated between

winter and spring. Mean annual air temperature was 9.7 °C with maximum and minimum daily air temperature of 16.7 °C and 2.8 °C, respectively. The soil was sandy loam, with electrical conductivity about 1.8 ds m⁻¹, pH about 7.3, organic matter about 0.76%, exchangeable K about 228 mg kg⁻¹ and extractable P about 12 mg kg⁻¹. The main growing weeds in the experimental area were *Convolvulus arvensis*, *Cirsium arvensis*, *Centaurea depressa*, *Chenopodium album*, *Melilotus officinalis* and *Avena fatua*.

The field was prepared well before sowing by ploughing twice with tractor followed by planking to make a fine seed bed. Seeds of wheat (*Triticum aestivum* L.) were planted at a target population of 350 plants m⁻² in 12 rows plots, 5 m long with spacing of 0.2 m between rows. Plots were separated by 1.5 m and blocks by 2.5 m unplanted distances. The field was immediately irrigated after planting to ensure uniform germination. All other agronomic operations except those under study were kept normal and uniform for all treatments.

The plants were harvested at maturity and traits such as plant height, number of grains per spike and 1 000-grains weight were recorded on 20 randomly selected plants in each plot. Seed protein content was recorded by seed analyzer device (Zeltex, ZX9500; Japan). Number of spikes per unit of area, grain yield and biological yield were obtained by harvesting an area of 3 m² from the middle of each plot, to avoid marginal effects. Analysis of variance was carried out using SAS computer software packages. The comparison of means was investigated using Duncan's Multiple Range Test (DMRT) at 0.05% probability.

RESULTS AND DISCUSSION

The effects of N fertilization, biofertilizer inoculation and weed interference on grain yield, yield components and protein content of wheat were presented in Table. The results obtained from the variance analysis of data indicated that nitrogen fertilization and weed interference had significant effects on all of the studied traits. Moreover, inoculation with biofertilizer affected significantly the studied traits except number of spikes per unit of area. Furthermore, interactions between N fertilization × weed interference were found significant in number of spikes per unit of area and

number of grains per spike. Interactions between N fertilization $\times$ biofertilizer inoculation showed significant effects on grain yield and biological yield of wheat.

Plant height (P H)

The plant height was significantly affected by nitrogen application, biofertilizer inoculation and weed interference (Table). The highest plant height was observed in the maximum rate of nitrogen application (200 kg N ha^{-1}) that did not differ significantly from 150 kg N ha^{-1} . The minimum plant height was recorded in control. Application of 200 kg N ha^{-1} increased plant height by 16.96%, compared to control (Table). Moreover, inoculated plants were higher than non-inoculated plants. Inoculation with biofertilizer increased plant height about 6.04% compared to non-inoculated plants. These results are in line with the findings of

other researchers (Zorita, Canigia, 2009; Daneshmand et al., 2012; Namvar et al., 2012; Liu, Shi, 2013). Weed interference significantly increased (2.81% over weed free treatment) the plant height (Table). Taller plants in the presence of weeds may occur due to plants competition for light and aerial resources as reported by Kolb and Gallandt (2012) and that is probably related to hormonal changes in plant tissues.

Number of spike per unit of area (N S)

Number of spikes m^{-2} increased with the increase of N application rate. Increasing of N fertilizer from 0 to 200 kg N ha^{-1} increased this trait by 6.26%. The lowest and the highest values of spike number were recorded in 0 and 200 kg N ha^{-1} , respectively (Table). Abedi et al., (2010); Kandil et al., (2011) and Liu, Shi (2013) reported similar results in wheat. Inoculation

Table. Effects of mineral nitrogen fertilizer, biofertilizer inoculation and weed control on yield and its components in wheat (*Triticum aestivum* L.)

Treatments	P H (cm)	N S (m^{-2})	N G (per spike)	1 000-G W (gr)	Pro (%)	G Y (gr m^{-2})	B Y (gr m^{-2})
Nitrogen rates (kg ha^{-1})							
N ₀	72.58 c	409.45 c	17.80 d	42.23 b	9.03 c	307.78 d	718.68 c
N ₁₀₀	78.96 b	425.46 b	27.58 c	43.01 a	10.35 b	510.08 c	1 209.45 b
N ₁₅₀	83.28 a	435.78 a	29.99 b	43.05 a	11.42 a	564.65 a	1 351.19 a
N ₂₀₀	84.89 a	435.11 a	31.38 a	43.06 a	11.83 a	587.89 a	1 416.54 a
Biofertilizer							
B _{non}	77.58 b	424.78 a	25.96 b	42.43 b	10.17 b	472.10 b	1 134.71 b
B _{with}	82.27 a	428.12 a	27.40 a	43.24 a	11.14 a	513.09 a	1 213.20 a
Weed control							
Weedy _{check}	81.03 a	401.15 b	25.75 b	42.15 b	10.32 b	441.50 b	1 080.85 b
Weed _{free}	78.81 b	451.74 a	27.61 a	43.52 a	10.99 a	543.71 a	1 267.07 a
Mean	79.92	426.45	26.68	42.84	10.66	492.60	1 173.96
Nitrogen (N)	*	**	**	*	**	**	**
Biofertilizer (B)	**	ns	**	*	**	**	**
Weed (W)	**	**	**	*	*	**	**
N $\times$ W	ns	**	**	ns	ns	ns	ns
N $\times$ B	ns	ns	ns	ns	ns	**	**
B $\times$ W	ns	ns	ns	ns	ns	ns	ns
CV (%)	6.52	8.24	7.93	6.78	9.19	8.36	9.41

P H: Plant Height, **N S:** Number of Spikes, **N G:** Number of Grains, **1 000-G W:** 1 000 Grains Weight, **Pro:** Protein Content, **G Y:** Grain Yield, **B Y:** Biological Yield – Mean values followed by the same letters in each column and treatment showed no significant difference by Duncan's Multiple Range Test ($P \leq 0.05$). *, ** and ns showed significant differences at 0.05, 0.01 probability levels and not significant, respectively

with biofertilizer showed no significant effects on number of spike per unit of area but the plants that were treated with biofertilizer showed more values of this trait than non-inoculated plants (Table). Moreover, the maximum values of spike number were recorded in the weed free treatment. The presence of weeds decreased the number of spike m^{-2} about 12.61% compared to the full control of weeds during the entire growth period (Table). These results demonstrated that weed infestation resulted in a lower number of spike, probably caused by competition for available resources, as has been observed previously (Riaz et al., 2006; Khan et al., 2007; Sary et al., 2009).

Spike number m^{-2} of wheat was significantly affected by the interaction effects of N fertilization and weed interference (Table). Generally, spike number of weed free treatments in each level of nitrogen application was higher than the weedy check at the same level of nitrogen application (Fig. 1). The highest value of spike number was recorded in the plants treated with 150 kg N ha^{-1} and weed free condition. The lowest spike number was observed in the application of 0 kg N ha^{-1} in the presence of weeds (Fig. 1).

Number of grains per spike (N G)

Variance analysis of data indicated that nitrogen fertilization, biofertilizer inoculation and weed interference had statistically significant effects on number of grains per spike (Table). The highest number

of grains per spike was recorded in 200 kg N ha^{-1} application and the least number of this trait was obtained in control. Application of 200 kg N ha^{-1} increased the number of grains per spike about 76.29% compared to control in each plant (Table). Similar trends were reported by Campuzano et al. (2011) and Piccinin et al. (2013). Inoculated wheat plants had statistically more number of grains per spike than non-inoculated plants. Inoculation with biofertilizer increased this trait by 5.54% compared to plants that were not treated with inoculum (Table). Vessey (2003) reported that *Azotobacter* sp. and *Azospirillum* sp. increased the available nitrogen in the soil which could enhance the grain number. Furthermore, the highest number of grains per spike were observed in the weed free treatment. Control of weeds resulted in 7.22% more number of grains per spike than weedy check (Table). Interaction effects of N fertilizer $\times$ weed interference were found significant in number of grains per spike (Table). In wheat the highest number of grains per spike was recorded in weed free treatment when treated with 200 kg N ha^{-1} . The least value of this trait was obtained from weedy check and non-fertilized plants (Fig. 1). Application of 200 kg N ha^{-1} in weed free treatment increased the number of grains per spike by 84.95% compared to control (Fig. 1).

1 000-grains weight (1 000-G W)

1 000-grains weight was significantly affected by nitrogen fertilization, biofertilizer inoculation and weed interference (Table). The increase of

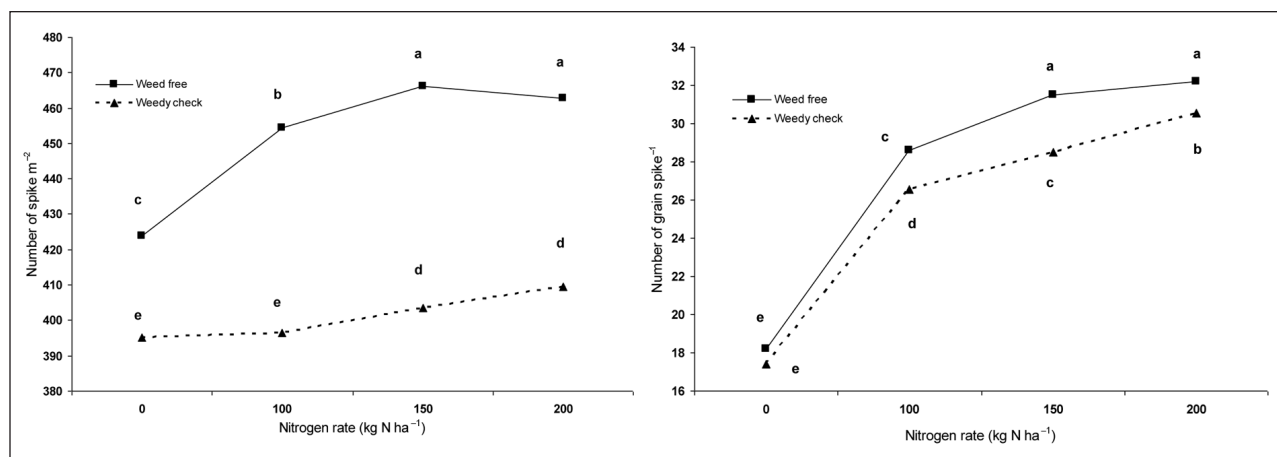


Fig. 1. Effects of different levels of nitrogen application and weed control (weed free and weedy check) on number of spike m^{-2} and number of grain spike $^{-1}$ in wheat (*Triticum aestivum* L.). Values with the same letters in each trait are not significantly different (DMRT at 5% level)

nitrogen application rate increased significantly the weight of 1 000-grains in wheat. The highest 1 000-grains weight was recorded in the application of 200 kg N ha⁻¹ while the lowest values of this trait were obtained from the unfertilized plants. Application of 200 kg N ha⁻¹ increased the 1 000-grains weight by 1.96% compared to control (Table). Inoculated plants showed about 1.91% higher 1 000-grains weight than non-inoculated plants. Previous studies justified the positive effects of nitrogen application (Abedi et al., 2010; Daneshmand et al., 2012) and biofertilizer inoculation (Zorita, Canigia, 2009; Kandil et al., 2011) on 1 000-grains weight. Moreover, the maximum 1 000-grains weight was recorded in the full control of weeds. Weed interference decreased 1 000-grains weight about 3.25% compared to the weed free treatment (Table). Decreasing 1 000-grains weight was attributed to smaller grains as a result of less nutrition at high competition conditions. These results are in accordance with the works of Riaz et al. (2006) and Sary et al. (2009).

Protein content (Pro)

As shown in Table, N application, biofertilizer inoculation and weed interference had significant effects on protein content of wheat grains. The highest protein content was observed in the application of 200 kg N ha⁻¹ that was statistically in par with the usage of 150 kg N ha⁻¹. The highest rate of nitrogen application increased grains protein content by 31.01% compared to control. Moreover, plants treated with *Azotobacter* sp. and *Azospirillum* sp. bacteria showed more protein content than control. Biofertilizer inoculation increased grains protein content about 9.53% compared to non-inoculated plants (Table). These results are in accordance with the reports of Khan et al. (2007); Sary et al. (2009) and Abedi et al. (2010). Rana et al. (2012) reported an enhancement of 18.6% in protein content with biofertilizer inoculation in wheat. It has been found that in case of an adequate supply of N in the soil, leaf senescence is slower and the plant is able to supply its seeds with N and photoassimilate for a longer period, which results in higher protein and grain yield (Azeez, 2009; Abedi et al., 2010). Moreover, the presence of weeds significantly decreased (6.49% compared to weed free treatment) the protein content of seeds (Table).

Grain yield (G Y)

The data presented in Table showed that all of the studied experimental factors (N fertilization, biofertilizer inoculation and weed interference) had significant effects on grain yield of wheat. Grain yield continuously increased with increase of N application, however, this trait of wheat increased until 150 kg N ha⁻¹ and further increase in N rate resulted in not significant grain yield increase. The highest rate of N fertilizer (200 kg N ha⁻¹) showed the greatest grain yield, however, this rate of nitrogen fertilizer was statistically in par with 150 kg N ha⁻¹ (Table). Application of 200 kg N ha⁻¹ increased grain yield per unit of area by 91.00%, compared to the least application of N fertilizer (control). Khan et al. (2007) investigated the nitrogen requirements of wheat and found that nitrogen fertilization positively influenced the grain yield. Furthermore, inoculated plants indicated higher grain yield than non-inoculated plants. Biofertilizer inoculation increased grain yield about 8.68% compared to control (Table). Similar results were reported on the effects of N fertilizer (Kizilkaya, 2008; Wortman et al., 2011; Scursoni et al., 2012) and biofertilizer (Saini et al., 2004; Sary et al., 2009; Namvar et al., 2012) on grain yield of different crop plants. The increase in the yield components, grain yield and protein content in the inoculated plants could be attributable to the exudation of plant growth regulators (PGRs), such as auxins and gibberellin and cytokinin by *Azotobacter* sp. and *Azospirillum* sp. beside the increase of the nutrient availability (Vessey, 2003). Piccinin et al. (2013) showed that the grain yield of wheat improved when wheat plants were grown with a combination of chemical N and biofertilizer inoculation.

Interaction effects of nitrogen fertilization and biofertilizer inoculation were found significant for grain yield of wheat (Table). At all rates of N application grain yield of inoculated plants was higher than of the non-inoculated plants at the same rate of nitrogen application (Fig. 2). The highest grain yield was recorded in inoculated plants with 200 kg N ha⁻¹ application. The lowest rate of N application showed the lowest grain yield in non-inoculated plants (Fig. 2). The study on the interactions between N application and inoculation showed that inoculation with *Azotobacter* sp. and *Azospirillum* sp. bacteria had more effects on grain

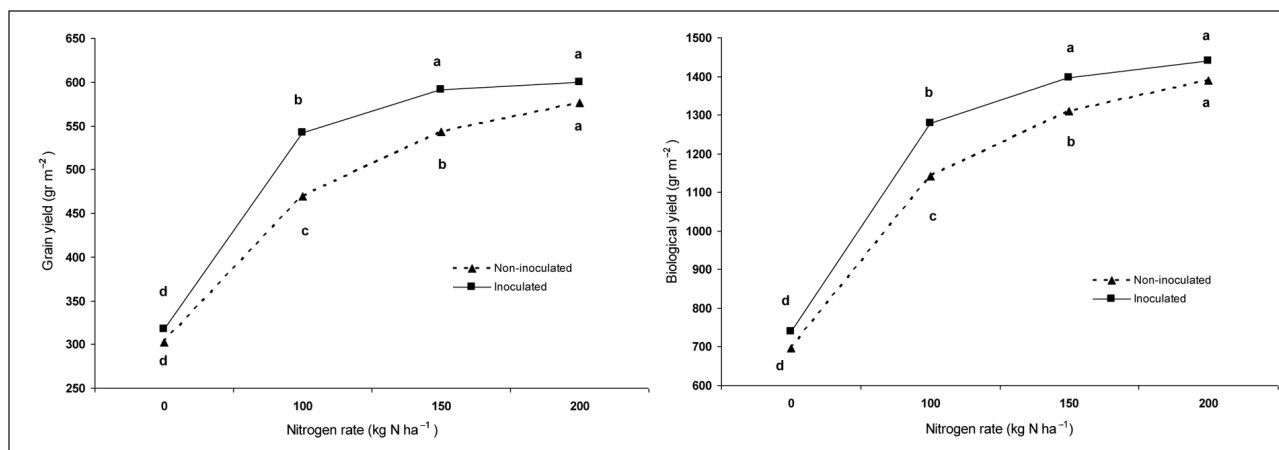


Fig. 2. Effects of different levels of nitrogen application under biofertilizer inoculation and non-inoculation on grain yield and biological yield in wheat (*Triticum aestivum* L.). Values with the same letters in each trait are not significantly different (DMRT at 5% level)

yield in 100 kg N ha⁻¹ than other levels of fertilizer application (Fig. 2).

Furthermore, the weed free treatment showed the maximum grain yield. Weeds interference decreased grain yield by 23.15%, compared to weeds control over the growth period (Table). Previous studies justified these results in various crops (Riaz et al., 2006; Khan et al., 2007; Azeez, 2009; Wortman et al., 2011; Armengot et al., 2013).

Biological yield (B Y)

Biological yield of wheat also showed the same trend as grain yield. As shown in Table, the highest biomass was obtained from the application of 200 kg N ha⁻¹, however, there was no significant difference among the application of 150 and 200 kg N ha⁻¹ in biological yield. Usage of 200 kg N ha⁻¹ increased the biological yield by 97.10%, compared to control. These results concur with observations of Kandil et al., (2011); Wortman et al., (2011); Daneshmand et al., (2012); Campuzano et al., (2012) and Liu, Shi (2013). Namvar et al. (2012) noted that the decrease in biomass production with decreasing supply of N was associated with decreases in both radiation interception and radiation use efficiency (RUE). Nitrogen is known to be an essential nutrient for plant growth and development involved in vital plant functions such as photosynthesis, DNA synthesis, protein formation and respiration (Blackshaw et al., 2005; Rana et al., 2012; Diacono et al., 2013). The growth parameters such

as LAI, biomass, and leaf photosynthesis significantly decreased due to unsatisfactory N availability (Khan et al., 2007; Azeez, 2009). The results obtained in this study indicated that usage of N fertilization had positive effects on wheat yield and its attributes. Supplementation with N increases the production of total dry matter in plants which can increase the potential of plant to produce greater plant height, spike number, grains number and weight that ultimately resulted in high grain and biological yield. Nitrogen fertilization increases the total dry matter for a number of reasons: (i) Nitrogen can increase the LAI in plants (Azeez, 2009). More LAI increases the interception of solar radiation by plants that results in higher accumulation in plants. (ii) Nitrogen can increase the photosynthesis rate in plants. Increasing photosynthetic rate with N fertilization can be attributed to increasing amount of chlorophyll pigments, since N is one of the major components of chlorophyll (Kizilkaya, 2008; Wortman et al., 2011; Diacono et al., 2013). In contrast, supplementation of adequate nitrogen for crops can increase their growth and development. Consequently, plants are able to produce more yield components that result in greater grain yield.

Moreover, wheat plants that were treated with biofertilizer had higher biomass than plants untreated with this inoculum. Inoculation with biofertilizer increased the biological yield about 6.91% compared to control (Table). The observed

benefits on wheat by biofertilizer inoculation seem to be due to the supply of N to the crop (Zorita, Canigia, 2009; Rana et al., 2012). Moreover, growth promoting substances (phytohormones) were produced by these organisms. Phytohormones as secondary metabolites are known to play a key role in plant growth regulation. They promote seed germination, root elongation and stimulation of leaf expansion. In addition, great root development and proliferation of plants in response to biofertilizer activities, i. e. *Azotobacter* sp. and *Azospirillum* sp., enhance water and nutrient uptake (Vessey, 2003; Saini et al., 2004; Kandil et al., 2011).

Interactions between different levels of N application and biofertilizer inoculation were found significant in biological yield (Table). In general, inoculation with *Azotobacter* sp. and *Azospirillum* sp. in all levels of N application increased biomass production in comparison with non-inoculated plants (Fig. 2). The highest biological yield was recorded at the plots of 200 kg N ha⁻¹ and biofertilizer inoculation. Control plots (non-fertilized and non-inoculated) had the lowest values of this trait (Fig. 2).

Furthermore, weed free treatment had the highest magnitude of biological yield. Weeds control over the entire growth period increased biological yield about 17.22% than the weedy check (Table). These results are in accordance with the works of Riaz et al., (2006); Sary et al., (2009) and Armengot et al. (2013). Dry matter production of crops depends on the amount of intercepting solar radiation and its conversion to chemical energy. When weeds infest an agricultural system, they encourage plants competition for resources. Thus crop net photosynthesis process will be affected due to less light penetration in the crop canopy as well as increase in the competition for available nutrient which will affect grain and biological yield. On the other hand, weeds control operations contribute to proper utilization of solar radiation and nutrient (Blackshaw et al., 2005; Petit et al., 2011; Scursoni et al., 2012).

Kolb, Gallandt (2012) stated that the understanding the ecology of both weeds and cereals is of paramount importance in developing non-chemical strategies that limit yield loss due to weeds whilst suppressing weed growth and weed seed deposition. Key mechanisms for weed manage-

ment include enhancing the cereal crops competitive advantage through practices that (i) reduce weed density, e. g. through use of a 'false seed-bed', and cultivation, possibly through the use of selective weed control with inter-row cultivation, and (ii) increase interspecific competition, including increased seeding rates, precise fertilizer and promoting quick canopy closure.

CONCLUSIONS

In summary, the results obtained from this study clearly indicated that wheat (*Triticum aestivum* L.) yield, yield components and protein content of grains had a strong association with the N fertilization, biofertilizer inoculation and weed interference. Higher rates of N fertilization and biofertilizer (*Azotobacter* sp. and *Azospirillum* sp.) inoculation increased plant height, spike number per unit of area, grains number per spike, 1 000-grains weight, grain yield, biological yield and grain protein content while weeds interference significantly decreased all these traits except plant height. Application of 150 kg N ha⁻¹ was statistically in par with 200 kg N ha⁻¹ in the majority of the studied traits. Moreover, our results showed that manual hoeing prevents weeds from being a limiting factor for crop productivity in wheat. It seems that a moderate N rate (about 150 kg N ha⁻¹) can be beneficial to improve growth, development and total yield of inoculated wheat. Thus, it is suggested to use a combination of organic and inorganic fertilizer to achieve the highest yield without a negative effect on grain quality that will lead to environmental conservation.

Received 16 June 2013
Accepted 21 August 2013

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Ali Namvar, Teymur Khandan

KVIEČIŲ ATSAKAS Į MINERALINIO AZOTO IR BIOLOGINIŲ (*AZOTOBACTER* SP. IR *AZOSPIRILLUM* SP.) TRĄŠŲ KOMPLEKSINĮ POVEIKĮ ESANT SKIRTINGAM PIKTŽOLĖTUMUI

S a n t r a u k a

Integruotos tręšimo strategijos augalininkystėje kūrimas yra svarbus siekiant padidinti pasėlių konkurencingumą, sumažinti piktžolių kiekį ir taršos azotu riziką.

Tyrimo tikslas – įvertinti mineralinio azoto ir biologinių trąšų kompleksinį poveikį kviečių (*Triticum aestivum* L.) derliui, atskirti jo komponentams, taip pat baltymo kiekiui esant skirtingam piktžolėtumui. Lauko bandymas atliktas pagal randomizuoto blokinio eksperimento planą (trys pakartojimai). Eksperimento metu tirti šie veiksniai: 1) keturios azoto koncentracijos (0, 100, 150 ir 200 kg N ha⁻¹), 2) du biologinių trąšų (*Azotobacter* sp. ir *Azospirillum* sp.) lygmenys (su ir be trąšų) ir 3) du piktžolėtumo lygmenys (su piktžolėmis ir be jų). Nustatytas stiprus ryšys tarp kviečių derliaus, jo komponentų, baltymo kiekio grūduose, azoto bei biologinių trąšų ir piktžolių. Didesni cheminių ir biologinių (*Azotobacter* sp. ir *Azospirillum* sp.) trąšų kiekiai lėmė augalų aukščio, varpų skaičiaus ploto vienetą, grūdų skaičiaus varpoje, tūkstančio grūdų svorio, grūdų derliaus, biologinio derliaus ir baltymo kiekio padidėjimą, o piktžolės sumažino visų šių rodiklių, išskyrus augalų aukštį, reikšmes. Be to, nustatyta, kad vidutinis azoto kiekis (apie 150 kg N ha⁻¹) gali būti naudingas siekiant pagerinti javų augimą, vystymąsi ir bendrą derlių. Taigi siekiant pagausinti derlių ir išvengti neigiamo poveikio jam, siūloma organines ir neorganines trąšas naudoti kompleksiskai.

Raktažodžiai: biologinė trąša, grūdų derlius, azotas, baltymo kiekis, piktžolių poveikis, kviečiai, derliaus komponentai