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EFFECT OF MACRO FERTILIZER ELEMENTS AND SEED RATE ON PRODUCTIVITY AND QUALITY OF TWO-ROW BARLEY

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Abstract

Two field experiments were carried out during 2015/2016 and 2016/2017 winter seasons at Agric. Res. Stat., Fac. Agric., Cairo Univ. Giza, Egypt to study the effect of four NPK fertilizer rates ($N_{15}P_{7.5}K_{12}$, $N_{30}P_{15}K_{24}$, $N_{45}P_{22.5}K_{36}$ and $N_{60}P_{30}K_{48}$) and four seeding rates *i.e.* 100 grains m^{-2} (22 kg $feddan^{-1}$), 150 grains m^{-2} (33 kg $feddan^{-1}$), 200 grains m^{-2} (44 kg $feddan^{-1}$) and 250 grains m^{-2} (55 kg $feddan^{-1}$) on barley growth, grain yield, grain quality and nitrogen use efficiency (NUE). For growth and yield attributes, results showed that NPK fertilizers rates had significant effect on growth, yield and its attributes, grain quality traits and NUE parameters except, spike length in both seasons. Also, plant height, weight of grains $spike^{-1}$ and 1000-grain weight were not significantly affected by NPK fertilizer rates in 2016/2017 season. All the studied traits increased by increasing NPK fertilizer rates during 2015/16 and 2016/17 seasons. The highest ($N_{60}P_{30}K_{48}$) rate gave the highest values of plant height, No. of shoots and spikes m^{-2} and Grains weight $spike^{-1}$ in both seasons. the greatest No. of shoots and spikes m^{-2}, Grain weight $spike^{-1}$ and spike length were obtained with the lower seeding rates (100 grains m^{-2}: 22 kg $feddan^{-1}$ or 150 grains m^{-2}) in both seasons, however, the tallest plants were observed at higher seeding rate (250 grains m^{-2} or 55 kg $feddan^{-1}$). For biological, grains and straw yields as well as harvest index, application of $N_{45}P_{22.5}K_{36}$ fertilizer rate produced the greatest of grain yield $feddan^{-1}$) and harvest index in both seasons. Straw yield $feddan^{-1}$ increased gradually with increasing NPK rate to $N_{60}P_{30}K_{48}$. Biological yieldof all fertilizer rate were significantly equal. Biological yield and straw yields significantly increased with increasing seeding rat up to 250 grains m^{-2} (55 kg $feddan^{-1}$) in both seasons. Seeding rate 200 grains m^{-2} (44 kg $feddan^{-1}$) produced the highest grain yield$feddan^{-1}$ and harvest index in both seasons. Regarding the grain quality, the highest values of 1000-grains weight, grain protein content and protein yield $feddan^{-1}$ were higher with increasing NPK rate to $N_{60}P_{30}K_{48}$ in both seasons. However, the highest grain carbohydrate % was recorded with $N_{15}P_{7.5}K_{12}$ fertilizer rate and the greatest carbohydrate yield $feddan^{-1}$ was obtainedwith $N_{45}P_{22.5}K_{36}$ fertilizer rate in both seasons. Seeding 200 grains m^{-2} (44 kg $feddan^{-1}$) gave the highest grain protein content, grain protein yield $feddan^{-1}$ and carbohydrate yield $feddan^{-1}$) in both seasons. The heaviest grain weight was produced with seeding rate (100 grains m^{-2} (22 kg $feddan^{-1}$) in both seasons. The effect of interaction NPK rate × seeding rate was only significant on protein and carbohydrate contents. Application of $N_{60}P_{30}K_{48}$ to plots seeded with 250 grains m^{-2} gave the highest grain protein content however, the highest carbohydrate content was observed with $N_{15}P_{7.5}K_{12}$ rate × 150 grains m^{-2} seeding rate treatment in both seasons. Regarding NUEvalues, the lower NPK fertilizer rates gave the highest NUE values for biological, grains and grain protein yields in both seasons. Seeding rate (250 grains m^{-2} (55 kg $feddan^{-1}$) gave the highest NUE of biological yield in both seasons. However the highest values of NUE of grain and grain protein yields were achieved with seeding 200 grains m^{-2}. The highest values of NUE of biological yield was obtained with N15P7.5K12 × seeding rate 250 grains m^{-2} (55 kg $feddan^{-1}$) during both seasons. However, the highest values of NUE of grain and grain protein yields were appeared with plants seeded with 150 or 200 grains m^{-2} and fertilized with N15P7.5K12 in 2016/17 season.

Key words: Barely, NPK, seeding rate, grain yield, NUE, protein %, carbohydrate %

Introduction

Barley (*Hordeum vulgare* L.) is a very important grain in the world today and it ranks the fourth in both quantity produced and in area of cultivation of cereal crops in the world. Barley is among the most tolerant crop plants under salinity stress, however, under the higher rates of salinity, its growth and yield production decreased. Barley also has a very good resistance to dry heat compared to other small grains. Barley requires for less water and can be cultivated in areas where irrigation water is less easily obtainable. The quality requirements for malting barley are strict and include disease-free kernels free from weathering, relatively low protein (<125 g kg^{-1}) and relatively large plump kernels (>800 g kg^{-1}) of uniform size (BMBRI, 2010). These quality parameters for malting may be affected by several factors. The most important of them are soil nutrition and plant density.

Fertilizers replace the nutrients that crops remove from the soil. Without the addition of fertilizers, crop yields and agricultural productivity would be significantly reduced. Mineral fertilizers are used to supplement the soil's nutrient stocks with minerals that can be quickly absorbed and used by crops. Nitrogen is an essential element for growth, development and biomass production; it also plays important roles in physiological functions (Kaur *et al.*, 2016). Boundless use of large amounts of N increases production costs and reduce the economic benefits (Ju *et al.*, 2009). Excess use of nitrogen causes environmental pollution by leaching nitrate ion into groundwater and runoff into surface water (Conley *et al.*, 2009). Excess of nitrogen associated with an increase in tiller formation, leaf area, leaf area index and leaf area duration and this effect leading to greater production of dry matter and grain yield (Ryan *et al.*, 2009). Abido and Seadh (2015) in Egypt, obtained maximum grain and straw yields of barley resulted by fertilizing Giza 131 cultivar with 75% inorganic nitrogen beside 25% poultry manure under sandy saline soils in North Nile Delta. Alazmani (2015) showed that grain yield, grain protein and plant height increased with increasing nitrogen fertilizer amount. Nitrogen increases leaf area, tiller formation and number, leaf area index and greenness duration and as well as, it led to more dry matter accumulation and grain yield. Kassa and Sorsa (2015) in Ethiopia, indicated that nitrogen and phosphorus integrated fertilizer of barley showed significant effect on biomass and grain yield and its attributes. Rawashdeh (2015) in Jordan, observed that plant height, spike length and protein percentage increased with any increase in the rate of N fertilizer up to 45 kg N/ha. Biruk (2016) in Ethiopia, stated that almost all agronomic of malt barley (*Hordeum vulgare* L.) parameters except harvest index increased in response to N rates up to 98.5 $kgha^{-1}$. However, N fertilizer rate of 75.5 N $kgha^{-1}$ for Bahat produced optimum yield with acceptable grain protein content for malt barley production in the study area. Hajighasemi, *et al.*, (2016) in Iran found that N fertilization rate 100 kg N/ha was optimum for grain barley production. O'Donovan, *et al.*, (2016) recommended that applying nitrogen at about 70 per cent of the soil test recommendation. Ali Heba, *et al.*, (2017) in Egypt, reported that application of 45 kg N/ fed or 25 kg N/fed along with coralline bio-fertilizer treatments produced the highest values of grain, biological and straw yields. Kozera, *et al.*, (2017) in Poland, reported that significantly higher grain yield and grain protein yield were obtained in spring barley following the application of 80 and 120 kg N/ha, as compared with the application of 40 kg N/ha. Kumar and Jha, (2017) in USA, reported that increasing the N rate from 56 to 168 kg/ha increased the barley plant height, total accumulated biomass/ m^2 and grain protein. Shah *et al.*, (2017) in the United Kingdom, observed that stem length, number of grains/spike and thousand grain weight were significantly affected by N while the effects of P and K were not significant. Grain yield increased when nitrogen rate was raised from 45 kg to 90 kg/ha. It was suggest the use of medium N-rate (45 kg/N ha) for reasonable yield (4.0 t/ ha) and acceptable grain quality. Etesami *et al.*, (2018) in Iran, found that nitrogen fertilizer application affect nitrogen use efficiency. The maximum and minimum nitrogen uptake was obtained in hull less barley (57%) and oat (27%), respectively. Phosphorus supplementation is essential globally, as soil. It is essential for grain yield and quality where P is concentrated in the barley grain with reported ranges from 3.57 to 4.68g kg^{-1} (Rogers *et al.*, 2017). El-Metwally *et al.,* (2018) in Egypt, obtained the highest wheat grain yield by sowing 65 kg seed $faddan^{-1}$ with adding 65 kg N + 37.5 kg P_2O_5 + 36 kg K_2O + Cerealin inoculation compared with other tested treatments. Biswanath, *et al.* (2019) reported that on an alkaline soil, grain yield increased with rate of P-application until 37kg P ha^{-1}.

The effects of seeding rate on barley yield and malting quality have also been variable. Most studies had indicated little or no improvement in yield at rates above 200 seeds/m^2. In general, increasing barley seeding rates tended to reduce protein concentration, but kernel plumpness and weight were also reduced (McKenzie *et al.*, 2005 and Edney, *et al.*, (2012) in Canada, found that higher seeding rates of two - row barley (400 vs. 200 seeds/m^2) produced barley with less grain protein and smaller, more uniformly sized kernels. O'Donovan *et al.,* (2011) in Canada, studying the effects of 200 and 400 seeds/m^2 seeding rare, found that kernel weight and plumpness were lower at the higher seeding rate; protein was also lower, maturity was earlier and kernels were more uniform. Also, O'Donovan, *et al.*, (2012) in Canada, mentioned that seeding barley at approximately 300 seeds/m^2 had the potential to optimize yield and important malting barley parameters such as protein concentration and kernel uniformity without significantly compromising kernel plumpness. Seeding rate above 300 seeds/m^2 should be avoided since it increased the risk of a decline in yield and plumpness and did not provide significant improvements in protein concentration or grain uniformity. Abd El-Rahman (2013) in sandy soils in Egypt, observed that seeding rate gave a clear and consistent significant effect on all growth and yield attributes. Increasing seeding rate from 30 to 45 and 60 kg/fad caused a significant decrease in spike length, number of grains/ spike, grain weight/spike and 1000-grain weight. The grain yield was however increased due to the increase in number of spikes/m^2. Kumar and Jha, (2017) in USA, mentioned that increasing the barley seeding rate from 38 to 152 kg/ha increased above ground biomass by 13% and grain yields by 29%. Perrott, *et al.,* (2018) in Canada, stated that plant density (244 and 355 plant/m^2) significantly affected spike length, kernel weight, test weight, protein content and starch content but, did not affect plant height, grain yield and N yield. The 355 plants/ m^2 density reduced, main stem, spike length, kernel weight and grain protein content compared with 240 plants/m^2. On the contrary, the 355 plants/m^2 increased grain test weight and grain starch concentration compared to 240 plants m^{-2}. Recently, Salama Heba (2019) in Egypt, found that increasing the seeding rate (100, 125, 150 kg/ha) significantly increased the total biological yield, grain yield and number of spikes/m^2. Although number of grains/ spike followed an opposite trend and decreased. The three tested seeding rates exerted a non-significant influence on the harvest index, plant height and 1000-grain weight.

There is little published information from Egypt on the effects of seeding and fertilizer rates on yield and quality of malting barley. Therefore the current investigation aimed to study effect of macro fertilizer elements and seed rate on productivity and quality of two-row barley Giza 128 cultivar.

Materials and Methods

Two field experiments were carried out at the Agric. Exp. Res. Sta. Giza, Fac. Agric., Cairo Univ., Egypt (30°02' N and 31°13' E, with an altitude of 30 meter) on a clay loamy soil during 2015/2016 and 2016/2017 winter seasons. Soil properties; a composite soil samples were collected from 0-30 cm depth during the study years before planting of 2015/2016 and 2016/2017 seasons were analyzed at Reclamation and Development Center Desert Soils, Faculty of Agriculture Research Park, Cairo University. The physical and chemical analysis of the experimental soil in first and second seasons is shown in table 1.

Table 1 cleared that the soil texture is clay loam, with low level of organic matter, slightly high soil pH and $CaCO_3$ contents. For that, the availability of nitrogen, phosphorus and potassium in soil are decreased. Comparing obtained soil test levels before planting with the critical levels showed that low level of available N and medium level for P and low level of K in the experiments soil which inefficient for growing barley.

Plant material

Barley grains of two-row barley cultivar Giza128 which was obtained from Barley Res. Dept., Field crop inst., Agric. Res. Centre, Giza, Egypt were mechanically counted using electric seed counter according to the tested seed rates.

Treatments and Experimental design

The four tested NPK fertilizer rates were $N_{15}P_{7.5}K_{12}$, $N_{30}P_{15}K_{24}$, $N_{45}P_{22.5}K_{36}$ and $N_{60}P_{30}K_{48}$ Kg fed^{-1} (4200 m^2). Phosphorus fertilizer rates and Potassium fertilizer rates were added at sowing. Nitrogen fertilizer rates were added in two equal doses; 25% at sowing and 75% at 25 days from sowing according to the testes treatment. The tested barley seeding rates were 100, 150, 200 and 250 grains m^{-2} corresponded to 22, 33, 44 and 55 Kg fed^{-1}, respectively. A split-plot design in a randomized complete block arrangement was used with three replications. The main plots were allotted to the four NPK fertilizer rates [$N_{15}P_{7.5}K_{12}$, $N_{30}P_{15}K_{24}$, N_{45} $P_{22.5}K_{36}$ and $N_{60}P_{30}K_{48}$ Kg fed^{-1}] and the four seeding rates (22, 33, 44 and 55 Kg

Table 1: Physical and chemical analysis of the experimental soil in 2015/ 16 and 2016/17 seasons.

Physical analysis	Seasons		Chemical analysis	Seasons	
	1st	2nd		1st	2nd
C. Sand (%)	2.2	4.0	pH (paste extract)	7.61	7.73
F. Sand (%)	35.7	30.9	EC (dS/m)	1.87	1.91
Silt (%)	29.6	31.2	Calcium carbonate (%)	3.67	3.47
Clay (%)	32.5	33.9	Organic matter (%)	2.25	2.09
Texture*	C. L.	C. L.			
Soil bulk density (g cm-3)	1.11	1.20			
Available nutrients (mg kg-1)	**Seasons**		**Total nutrients**	**Seasons**	
	1st	2nd		1st	2nd
Nitrogen	30. 8	31.3	Nitrogen (mg kg-1)	940	910
Phosphorus	8.23	8.86	Phosphorus (mg kg-1)	660	710
Potassium	223	212	Potassium (%)	2.12	2.25

*C.L. = clay loam

fed^{-1}) were devoted to sub-plots. Each sub-plot consisted of 15 rows of 0.20 m in width and 3.5 m in length.

Cultural practices

The previous summer crop was maize in both seasons. Sowing dates was 20th of November in 2015/16 and 5th of December in 2016/17 seasons. Each seed rate was hand drilled in rows. Phosphorus fertilizer rates in form of calcium superphosphate (15% P_2O_5) and Potassium fertilizer rates in form of potassium sulphate (48% K_2O) were added at sowing. Nitrogen fertilizer rates in form of ammonium nitrate (33.5% N) were added in two equal doses; 25% at sowing and 75% at 25 days from sowing according to the testes treatment. All other cultural practices were done as recommended for barley crop at the Agricultural Experimental and Research Station at Giza, Fac. Agric., Cairo University the during both growing seasons.

Data collection

At harvest, plant height of ten random shoots in each plot was determined at maturity as the height of plant from the soil surface to the spike apex where awns were not included in measurements using steal. Barley shoots of two samples each was 0.25 m of two rows wide (40 cm) were aboveground cut and then number of shoots and spikes were handily counted. These numbers were transformed to number of shoots or spikes per square meter. Ten random spikes were collected from each plot to measure spike length, weight of grains spike^{-1} and number of grains spike^{-1}.

To determine the shoots, grain and straw yields, the aboveground barley shoots (stems, leaves and spikes) of a one random square meter from each sub plot were cut at the soil surface and leaved for aerial drying for one week until a constant weight, then weighted and threshed to obtain grains of barley. The aboveground shoot was defined as biological yield and was converted to an area basis (tons fed^{-1}). Grains of the individual plots after removing awns and debris were weighted and converted to an area basis (tons fed^{-1}). Straw yield was calculated as the difference between aboveground biomass (biological yield) and grain yield. Seed index was calculated as mean weight of 1000 clean sound grains counted twice using electric seed counter. Grain yield was adjusted to a 12.5% moisture basis. Harvest index (%) as an indicator of photosynthetic efficiency was calculated as the ratio of grain weight m^{-2} to the shoots weight m^{-2}, expressed as a percentage.

Grain samples were milled; then accurately weighted at 0.5 g for digestion. The collected grain samples were subjected to analysis using the wet digestion in H_2SO_4-H_2O_2 mixture as described by Parkinson and Allen (1975) to measure nitrogen content of grains using the micro Kjeldahl method (Black, 1965). Also, Total carbohydrate percentage in the barley grains was determined using the method described by Herbert *et al.,* (1971) at Food Science Department lab, Faculty of Agriculture, Cairo University, Egypt.

Grain protein content according to Merrill and Watt (1973) and FAO (2013) was calculated as follow:

Grain protein content = grain nitrogen percentage × 5.83

Grain protein yield was estimated as the following equation:

Grain protein yield (kg fed^{-1}) =

$$\frac{Grain\ yield\ (ton/fed) \times protein\%}{100}$$

Grain carbohydrates yield (Kg fed-1) was estimated as the following equation:

Carbohydrates yield = Grain yield (Kg fed-1) × carbohydrates % ÷100

Nitrogen use efficiency (NUE) for biological yield (BY), grain yield (GY) and grain protein yield (GPY) was calculated according to Moll *et al*. (1982) and Ahmed and Hassan (2019) as follows:

$$NUE_{BY} = \frac{Bbio\log ical\ yield\ (kg/fed)}{Nitrogen\ applied\ (kg/fed)},$$

$$NUE_{GY} = \frac{Grain\ yield\ (kg/fed)}{Nitrogen\ applied\ (kg/fed)}$$

$$NUE_{GPY} = \frac{Grain\ yield\ (kg/fed) \times protein\%}{Nitrogen\ applied\ (kg/fed)}$$

Statistical Analysis

All data are presented as mean values of three replicates. Data were analyzed statistically for analysis of variance (ANOVA) following the method described by Gomez and Gomez (1984). MSTATC computer software was used to carry out statistical analysis (Bricker, 1991). The significance of differences among means was compared by using Least Significant Difference (LSD) test (Steel and Torrie, 1997).

Results and Discussion

Growth and yield attributes

Effect of NPK fertilizer rate

As shown in table 2, increasing NPK fertilizer rate

Table 2: Effect of NPK fertilizer rate ongrowth and grain yields attributes of two row barley cv.Giza 128 in 2015/16 and 2016/17 seasons.

Traits	Season	NPK Fertilizer rate				LS
		$N_{15}P_{7.5}K_{12}$	$N_{30}P_{15}K_{24}$	$N_{45}P_{22.5}K_{36}$	$N_{60}P_{30}K_{48}$	$D_{0.05}$
Plant height (cm)	2015/16	108.08 d	111.39 c	113.93 b	116.15 a	1.09
	2016/17	104.93	105.23	105.59	106.96	ns
Shoots/ m^2(no)	2015/16	377.2 c	412 b	445.4 a	462.5 a	29.3
	2016/17	313 b	323.5 b	322.7 b	369.5 a	33.7
Spikes/ m^2(No.)	2015/16	309.7 c	319 bc	335.5 b	355.7 a	17.6
	2016/17	266 b	279 b	283.8 b	316.2 a	28.8
Grains/ spike (g)	2015/16	1.24 b	1.30 ab	1.36 a	1.39 a	0.08
	2016/17	1.27	1.25	1.32	1.36	ns
Spike length (cm)	2015/16	7.9	8.2	8.4	8.4	ns
	2016/17	7.2	7.3	7.5	7.5	ns

from $N_{15}P_{7.5}K_{12}$ up to $N_{60}P_{30}K_{48}$ significantly ($p<0.05$) enhanced plant height and weight of grains spike^{-1} in the 2015/16 season, No. of shoots m^{-2} and No. of spikes m^{-2} in 2015/16 and 2016/17 seasons. Results in table 2 reveal that fertilizing barley with $N_{60}P_{30}K_{48}$ gave the highest values of plant height (116 and 107 cm), No. of shoots m^{-2} (462.5 and 369.5), No. of spikes m^{-2} (355.7 and 316.2), weight of grains spike^{-1} (1.687 and 1.57 g) and spike length (8.44 and 7.54 cm) at harvest in 2015/16 and 2016/17 seasons, respectively. However, the lowest values of the above mentioned traits were the minimum at $N_{15}P_{7.5}K_{24}$ fertilizer rate in both seasons, respectively.

On the other hand, the positive effect of NPK fertilizer rate on spike length did not reach to the level of significance ($p<0.05$). The increment in growth and yield attributes may be due to the effects of NPK on enhancing root growth and the availability of barley plants to uptake of nutrient and dry matter accumulation. Excess of nitrogen associated with an increase in tiller formation, leaf area, leaf area index and leaf area duration and this effect leading to greater production of dry matter and grain yield (Ryan *et al.,* 2009). Such increment in plant height and spike length accompanied with increasing N rate might be attributed to the stimulation of internodes elongation and enhancing tillering growth (Abd El-Hameed (2011).

These results are in harmony with those of Alazmani (2015), Kassa and Sorsa (2015), Rawashdeh (2015), Biruk (2016) in Ethiopia, O'Donovan *et al*., (2016), Rogers *et al.,* (2017), El-Metwally *et al*., (2018), Abdel-Lattif *et al.,* (2019) with wheat, Etesami *et al.,* (2018) and Biswanath *et al.,* (2019) who mentioned that growth and yield components of barley crop increased with increasing application of NPK fertilizer till a certain rate according to the experimental condition.

Effect of seed rates

The growth and yield attributes of barley was significantly ($p<0.05$) affected by seed rates in both seasons table 3. Barley plants were significantly taller with increasing seeding rates in both seasons. The tallest (115.2 and 107.4 cm) plants were observed with seeding 250 grains m^{-2} (55 kg seeds feddan^{-1}), however, the shortest (109.6 and 103.7 cm) ones were recorded with seeding 100 grains m^{-2} (22 kg seeds feddan^{-1}) in both seasons, respectively. Number of shoots m^{-2}, No. of spikes m^{-2}, grain weight spike^{-1} and spike length values were lower with increasing seeding rate from 100 grains m^{-2} (22 kg seeds feddan^{-1}) to 250 grains m^{-2} (55 kg seeds feddan^{-1}) as a result for reduction in space between plants. The results show that the highest plant density 250 grains m^{-2} (55 kg feddan^{-1}) reduced No. of shoots m^{-2} by 28.8 and 15.8 %, No. of spikes m^{-2} by 13.3 and 14.1%), Spike grains weight by 12.8 and 14.8% and Spike length by 16.3 and 17.0% in 2015/16 and 2016/17 seasons, respectively compared with the seeding rate 100 grains m^{-2} (22 kg feddan^{-1}). It could be concluded that using 100-150 seeds m-^{2} were the optimum plat density for achieving the highest values of grain attributes. These results are in agreement with Perrott, *et al*., (2018) in Canada who stated that plant density (244 and 355 plant m^{-2}) significantly affected spike length but, did not affect plant height, grain yield and N yield. The 355 plants/m^2 density reduced main stem and spike length compared with 240 plants/m^2.

Table 3: Effect of seeding rates on growth and yields attributes of two row barley Giza 128 in 2015/16 and 2016/17 seasons.

Traits	Season	Seeding rates*				LS
		S_1	S_2	S_3	S_4	$D_{0.05}$
Plant height (cm)	2015/16	109.56 c	111.48 b	113.29 b	115.23 a	1.83
	2016/17	103.70 c	105.28 bc	106.33 ab	107.40 a	2.06
Number of shoots m^{-2}	2015/16	487.00 a	431.17 b	400.17 c	378.75 d	18.1
	2016/17	357.67 a	332.00 b	330.00 bc	309.00 c	21.0
Number spikes m^{-2}	2015/16	351.50 a	333.17 b	325.00 bc	310.17 b	15.6
	2016/17	306.83 a	288.17 ab	281.00 ab	269.00 a	26.3
Grains weight spike^{-1} (g)	2015/16	1.41 a	1.36 a	1.28 b	1.25 b	0.05
	2016/17	1.40 a	1.34 b	1.23 c	1.22 c	0.04
Spike length (cm)	2015/16	8.72 a	8.45 ab	8.17 b	7.50 c	0.53
	2016/17	7.90 a	7.54 ab	7.35 b	6.75 c	0.38

*S_1= 100 grains m^{-2} (22 kg feddan^{-1}), S_2= 150 grains m^{-2} (33 kg feddan^{-1}), S_3 = 200 grains m^{-2} (44 kg feddan^{-1}) and S_4= 250 grains m^{-2} (55 kg feddan^{-1}

Effect of the interaction

The results indicate that the interaction between NPK fertilizer rates and seeding rates had no significant effect on plant height, number of tillers m^{-2}, number of spikes m^{-2}, weight of grains/spike and spike length except weight of grains/spike in 2016/2017 season. The significant ($p<0.05$) effect of the interaction between seeding rates and NPK fertilizers application on grain weight $spike^{-1}$ is illustrated in Fig. 1. The heaviest grains $spike^{-1}$ (1.48 g) was produced from plots received $N_{60}P_{30}K_{48}$ fertilizer rate and sown by 250 grains m^{-2} (55 kg $feddan^{-1}$). Whereas, the lowest value grain weight/spike (1.12 g) was recorded at $N_{15}P_{7.5}K_{12}$ fertilizer rate × 250 grains m^{-2} (55 kg seed $feddan^{-1}$) interaction. It is obvious from these results that increasing NPK fertilizer rate significantly increased grains weight $spike^{-1}$ at different seeding rates.

Biological, grain and straw yields as well as harvest index

Effect of NPK fertilizer

The results of biological, grain and straw yields and harvest index in 2015/16 and 2016/17 seasons are presented in table 3. It is clear from these results that there were significant ($p<0.05$) differences in grain yield /feddan (4200m^2) in both seasons, straw yield in 1st season and harvest index in both seasons among NPK fertilizer rate. The highestbarley biological yield $feddan^{-1}$ (8.870 and 6.320 tons), grain yield $feddan^{-1}$ (3.536 and 2.530 tons) and straw yield $feddan^{-1}$ (6.020 and 4.080 tons) in both seasons, respectively, were obtained with adding $N_{45}P_{22.5}K_{36}$. However, the lowest values of the above mentioned traits were obtained with $N_{15}P_{7.5}K_{12}$ application in both seasons, respectively. Biological yield $feddan^{-1}$ and straw yield in 2nd season followed the same trend, where increasing NPK fertilizer rate gave the highest value. However, the positive effect of NPK fertilizer rates on this trait did not reach the level of significance ($p<0.05$).

Results also show that harvest index was significantly ($p<0.05$) influenced by mineral NPK fertilizer rate in 2015/16 and 2016/17 seasons. The greatest harvest index (41.74 and 41.41%) in both seasons, respectively, was obtained when barley fertilized by $N_{45}P_{22.5}K_{36}$. The increase in biological, grain and straw yields as well as harvest index with application of NPK fertilizer may be due to the promoting effect of NPK fertilizer on number of shoots m^{-2}, spikes and grain weight $spike^{-1}$ table 2. These results are in line with those of Abido and Seadh (2015), Alazmani (2015), Amanullah, (2015), Kassa and Sorsa (2015), Hajighasemi, *et al*., (2016) in Iran, O'Donovan *et al*., (2016), Ali Heba, *et al*., (2017) in Egypt, Kozera, *et al*., (2017) in Poland, Kumar and Jha,

Table 3: Effect of NPK fertilizer rate on biological, grain and straw yields as well asharvest index of two - rowbarleycv. Giza 128 in 2015/16 and 2016/17 seasons.

Traits	Season	NPK Fertilizer rate				LSD 0.05
		$N_{15}P_{7.5}K_{12}$	$N_{30}P_{15}K_{24}$	$N_{45}P_{22.5}K_{36}$	$N_{60}P_{30}K_{48}$	
Biological yield $feddan^{-1}$(ton)	2015/16	8.270	8.330	8.470	8.870	ns
	2016/17	5.840	6.050	6.140	6.320	ns
Grain yield $feddan^{-1}$(ton)	2015/16	2.620 c	3.018 b	3.536 a	2.848 bc	0.340
	2016/17	2.170 b	2.190 b	2.530 a	2.240 b	0.130
Straw yield $feddan^{-1}$ (ton)	2015/16	5.650 ab	5.310ab	4.930 b	6.020 a	0.722
	2016/17	3.670	3.860	3.600	4.080	ns
Harvest index (%)	2015/16	31.95 b	36.47 b	41.74 a	32.22 b	5.05
	2016/17	37.53 ab	36.48 b	41.41 a	35.62 b	3.93

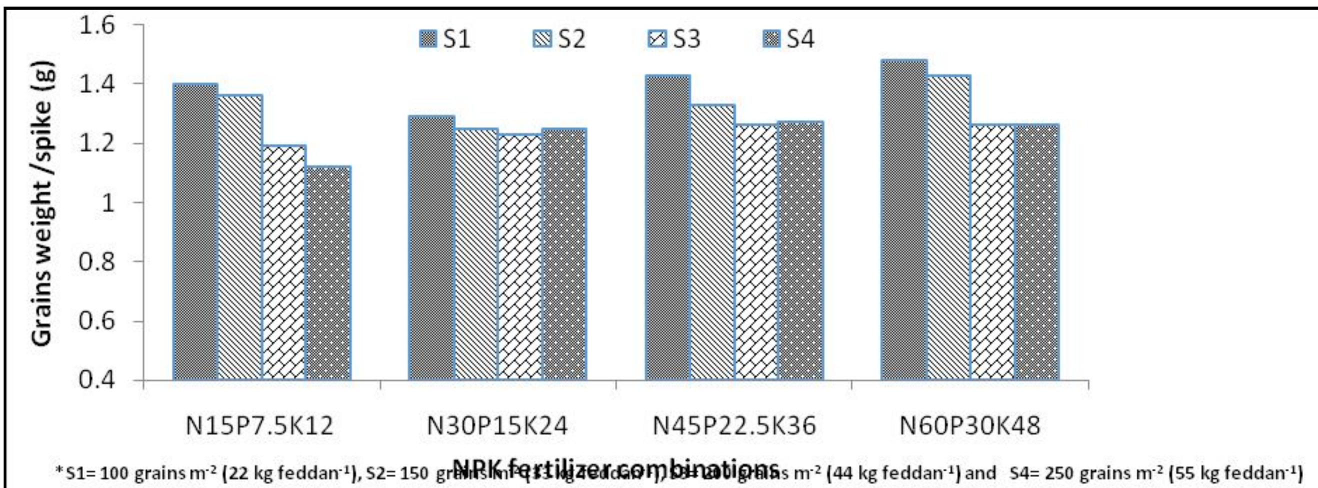

Fig. 1: Effect of NPK fertilizer rates and seeding rates interaction on grains weight $spike^{-1}$ (g) of two row barley Giza 128 in 2016/2017 season.

Table 4: Effect of seeding rates on biological, grain and straw yields as well as harvest index of two - rowbarley Giza 128 in 2015/16 and 2016/17 seasons.

Traits	Season	Seeding rates*				LSD$_{0.05}$
		S_1	S_2	S_3	S_4	
Biological weight feddan^{-1}(ton)	2015/16	7.93 c	8.33 bc	8.56 b	9.11 a	0.53
	2016/17	5.67 c	5.88 bc	6.14 b	6.66 a	0.29
Grain yield feddan^{-1}(ton)	2015/16	2.64 c	2.93 b	3.35 a	3.11 ab	0.24
	2016/17	2.14 b	2.31 c	2.47 a	2.22 bc	0.13
Straw yield feddan^{-1}(ton)	2015/16	5.29 b	5.41 ab	5.21 b	6.00 a	0.61
	2016/17	3.52 b	3.57 b	3.67 b	4.45 a	0.30
Harvest index (%)	2015/16	33.59 b	35.36 ab	39.12 a	34.31 b	3.79
	2016/17	37.87 a	39.36 a	40.38 a	33.43 b	2.52

*S_1= 100 grains m^{-2} (22 kg feddan^{-1}), S_2= 150 grains m^{-2} (33 kg feddan^{-1}), S_3= 200 grains m^{-2} (44 kg feddan^{-1}) and S_4= 250 grains m^{-2} (55 kg feddan^{-1}).

(2017) in USA, Shah, *et al*., (2017) in the United Kingdom and Rogers *et al.,* (2017), Wali, *et al*., (2018) in Egypt, El-Metwally *et al*., (2018) with wheat, Etesami *et al.,* (2018) and Biswanath *et al.,* (2019) and Shrestha and Lindsey (2019) in USA who mentioned that growth and yield of barley crops increased with increase application of N or NPK fertilizers.

Effect of seed rate

Results in table 4 pointed out that the tested barley seeding rates had a significant ($p<0.05$) effect on biological, grains and straw yields as well as harvest index in 2015/16 and 2016/47 seasons. Barley biological yield feddan^{-1} was significantly higher by increasing seeding rates. The greatest biological weights feddan^{-1} were 9.11 and 6.66 tons in both seasons, respectively, with seeding 250 grains m^{-2} (55 kg feddan^{-1}) compared with the lesser seeding rate. The highest grain yield of barley feddan^{-1} (3.35 and 2.47 tons) in both seasons, respectively were recorded as a result of sowing barley with 200 grains m^{-2} (44 kg feddan^{-1}) compared to other seeding rates. Straw yield was significantly higher by increasing seeding rates in both seasons. Straw yield of barley increased by 13.4 and 26.4% when applied seeding rate 250 grains m^{-2} (55 kg feddan^{-1}) compared with lesser seeding rates in both seasons, respectively. For harvest index results in table 4 revealed the significant effect of seeding rates on barley harvest index in 2015/16 and 2016/17 seasons. The highest values of harvest index with no significant differences were achieved by seeding 100-200 grains m^{-2} (22- 44 kg seeds feddan^{-1}) in both seasons. This reduction in harvest index in high seeding rate might be due to the competition for nutrients, moisture and solar radiation in higher plant population per unit area. These results are in harmony with those of Kumar and Jha, (2017) in USA, who mentioned that increasing the barley seeding rate from 38 to 152 kg/ha increased aboveground biomass by 13% and grain yields by 29%.

Effect of the interaction

The statistical analysis of the experiment data showed the interaction effect between NPK rates and seeding rate on biological, grain and straw yields and harvest index in 2015/16 and 2016/17 seasons was not significant ($p < 0.05$).

Some grain quality traits

Effect of NPK fertilizer

Combinations of different NPK rates affected all studied grain quality traits in 2015/16 and 2016/17 seasons as shown in table 5. Thousand-grain weight was significantly affected by NPK rates ranging between 51.95 and 59.54g at different NPK rates. Higher rates of NPK produced heavier grains. The highest value of 1000-grain weight (59.5 and 59.2g) was recorded from $N_{60}P_{30}K_{48}$ application and the lowest (53.1 and 51.9g) ones in both seasons, respectively, was obtained from $N_{15}P_{7.5}K_{12}$ application. In spite of the gradual increase in seed index as a result for increasing NPK rates, this increase did not reach the level of significance ($p<0.05$) in the second season. McKenzie, *et al.,* (2005) pointed to the proportion of kernels that were plump or thin was affected by cultivar, N fertilizer application and the interaction of cultivar and N rate. Two - row cultivars had a higher proportion of plump kernels and a lower proportion of thin kernels than six-row cultivars. Application of N fertilizer reduced

Table 5: Effect of NPK fertilizer rate on some grain quality traits of two - row barley cv. Giza 128 in 2015/16 and 2016/17 seasons.

Traits	Season	NPK Fertilizer rate				LSD$_{0.05}$
		$N_{15}P_{7.5}K_{12}$	$N_{30}P_{15}K_{24}$	$N_{45}P_{22.5}K_{36}$	$N_{60}P_{30}K_{48}$	
1000-grains, g	1st	53.14 c	56.90 b	57.28b	59.54 a	2.22
	2nd	51.95	57.32	57.84	59.17	Ns
Grain protein, %	1st	13.10 d	13.71 c	14.09 b	16.22 a	0.31
	2nd	14.06 d	14.53 c	16.04 b	17.59 a	0.17
Grain protein yi eld, kg feddan^{-1}	1st	343.29 c	414.59 b	498.71 a	461.92 ab	48.99
	2nd	306.40 b	318.94 b	407.35 a	393.70 a	20.41
Grain carbo-hydrate, %	1st	70.15 a	68.54 b	68.45 b	66.40 c	0.18
	2nd	70.28 a	69.74 b	68.90 c	59.97 d	0.34
Grain carbohy-drate (kg/fed)	1st	1837.90 b	2067.92 b	2419.83 a	1890.61 b	233.20
	2nd	1528.42 b	1526.12 b	1745.95 a	1342.97 c	77.06

the proportion of kernels that were plump. The highest fertilizer rate ($N_{60}P_{30}K_{48}$) significantly ($p<0.05$) increased barley protein content (16.2 and 17.6%). The greatest grain protein yields feddan^{-1} (498 and 407kg) in both seasons, respectively, were achieved with 200 seeds/m^2 (44Kg seeds feddan^{-1}).

Grain carbohydrate content (%) and grain carbohydrate yield feddan^{-1} were significantly ($p<0.05$) affected by NPK rate in both seasons table 5. Increasing NPK combinations rates significantly reduced carbohydrate content in both seasons of study. The lowest rate of NPK ($N_{15}P_{7.5}K_{12}$) gave the highest grain carbohydrate content (70.15 and 70.28%) in both seasons, respectively. However, the highest grain carbohydrate yieldfeddan^{-1} (2419.83 and 1745.95 kg) in both seasons, respectively was recorded with $N_{45}P_{22.5}K_{36}$ application. These results are in line with those of Rawashdeh (2015), Biruk (2016) in Ethiopia, Kozera, *et al.,* (2017) in Poland, Kumar and Jha, (2017) in USA, Shah, *et al.,* (2017) in the United Kingdom, Wali, *et al.,* (2018) in Egypt and Shrestha and Lindsey (2019) in USA whom reported the simulating effect of NPK fertilizer on protein content. On the other hand, Etesami, *et al.,* (2018) showed that, grain protein correlated significantly positive to grain nitrogen content (0.75). Nitrogen use efficiency had significant positive relationship with seed protein percent (0.51 respectively) Abdel-Lattif *et al.,* (2019 b) in Egypt with corn. McKenzie, *et al.,* (2005) pointed to grain protein concentration was affected by cultivar, N fertilizer application and the interaction of cultivar and N rate. Grain protein concentrations were generally acceptable when the N was between 25 and 40 kg N Mg^{-1} grain yield. Application of P, K or S did not significantly affect grain protein concentration.

Table 6: Effect of seeding rates on grain quality traits of two - rowbarley cv. Giza 128 in 2015/16and 2016/17 seasons.

Traits	Season	Seeding rates*				LSD$_{0.05}$
		S_1	S_2	S_3	S_4	
1000-grains (g)	2015/16	58.88 a	55.90 b	56.50 ab	55.58 b	2.52
	2016/17	59.50 a	56.75 b	56.16 bc	53.86 c	2.56
Grain protein (%)	2015/16	14.16 c	14.71 b	15.14 a	13.11 d	0.21
	2016/17	15.39 c	15.84 b	16.40 a	14.60 d	0.17
Grain protein yi eld (kg feddan^{-1})	2015/16	373.52 c	428.91 b	507.46 a	408.62 ab	39.78
	2016/17	330.76 c	366.10 b	405.48 a	324.04 c	21.19
Grain carbo-hydrate (%)	2015/16	68.59 a	68.30 bc	68.21 c	68.44 b	0.14
	2016/17	67.00 c	67.58 a	67.03 c	67.28 b	0.22
Grain carbohydrate yield (kg feddan^{-1})	2015/16	1811.06 c	1999.65 b	2278.63 a	2126.91 ab	164.60
	2016/17	1435.03 c	1560.97 b	1658.71 a	1488.76 bc	89.66

*S_1= 100 grains m^{-2} (22 kg feddan^{-1}), S_2= 150 grains m^{-2} (33 kg feddan^{-1}), S_3 = 200 grains m^{-2} (44 kg feddan^{-1}) and S_4= 250 grains m^{-2} (55 kg feddan^{-1}

Effect of seed rates on some grain quality traits

Results in table 6 show that barley seeding rates had a significant ($p<0.05$) effect on 1000-grain weight, protein content, protein yield feddan^{-1}, carbohydrate content and carbohydrate yield feddan^{-1} in 2015/16 and 2016/17 seasons.

The results given in table 6 suggest that increasing seeding rates resulted in a decrease in the 1000- grain weight in both seasons. The greatest 1000- grain weight (58.88 and 59.5g) in 2015/16 and 2016/17 seasons, respectively was recorded from plants seeded with 100-grain m^{-2} (22 Kg seeds feddan^{-1}). The reduction in grain weight at higher seeding rates might be due to increased interplant competition for light interception and available soil water which directly decreased photosynthetic rate and resulted in reduction of seed size. McKenzie, *et al.,* (2005) pointed to the kernel size was significantly affected by seeding date and seeding rate, but not by the interaction of the two. Higher seeding rates reduced the proportion of kernels that were plump.

Protein percentage significantly reacted with seeding rate rates during both seasons, so the peak of this percentage (15.4 and 16.40%) in the first and second seasons, respectively was resulted from seeding 200 grains m^{-2} (44 kg feddan^{-1}). Protein yield feddan^{-1} of barley was significantly affected by different seeding rates in both seasons. The greatest protein yield (507.46 and 405.48 kg feddan^{-1}) in both seasons, respectively, was recorded with sowing 200 grains m^{-2} (44 kg feddan^{-1}). The previous results are in accordance with those of McKenzie, *et al.,* (2005) who pointed to higher seeding rates (150, 200, 250, 300 and 350 viable seeds m^{-2}) reduced grain protein concentrations, with an average decline of 4 mg g^{-1} from the highest two seeding rates to the lowest seeding rate. O'Donovan *et al.,* (2016) in Canada, repotted that increasing the seeding rate up to 300 seeds/m^2 resulted in higher values of quality parameters (germination and Kolbach indices, lower β-glucan and better endosperm). These results are in harmony with those of Perrott, *et al.,* (2018) in Canada stated that plant density (244 and 355 plantm^{-2}) significantly affected kernel weight, protein content and starch content. The 355 plantsm^{-2} density reduced kernel weight and grain protein content compared with 240 plantsm^{-2}. On the contrary, the 240 plantsm^{-2} increased grain starch concentration compared with 355 plantsm^{-2}. On the other hand, Kumar and

Jha, (2017) in USA, mentioned that seeding rate did not affect the barley test weight under high N and barley protein (%).

For grain carbohydrate content and carbohydrate yield of barley in 2015/16 and 2016/17 seasons, results table 6 reveal that sowing barley with 100 grains m^{-2} (22 kg $feddan^{-1}$) in 2015/2016 season or 150 grains m^{-2} (33 kg $feddan^{-1}$) in 2016/17 season gave the highest carbohydrate content (68.59 or 67.58%), respectively. The greatest significant carbohydrate yield $feddan^{-1}$ (2278.63 and 1658.71 kg) was recorded in plots seeded with 200 grains m^{-2} (44 kg seeds $feddan^{-1}$) followed by 250 grains m^{-2} 55 kg seeds $feddan^{-1}$ (2126.91 and 1488.76 kg), respectively, in both seasons. However, the lowest carbohydrate yield $feddan^{-1}$ in both seasons was obtained from seeding 100 grains m^{-2}. These results are in harmony with those of O'Donovan, *et al.,* (2012) in Canada, who mentioned that under five different seeding rates (100, 200, 300, 400 and 500 seeds m^{-2}). Seeding barley at approximately 300 seeds m^{-2} had the potential to optimize yield and important malting barley parameters such as protein concentration and kernel uniformity without significantly compromising kernel plumpness. Seeding above 300 seeds/m^2 should be avoided since it increased the risk of a decline in yield and plumpness and did not provide significant improvements in protein concentration or grain uniformity. On contrary, Rawashdeh (2015) in Jordan who found that seeding rate effect on protein percentage was insignificant. There are negative relationship between protein percentage and increasing seeding rates.

Table 7: Some grain quality parameters of two - row barley cv. Giza 128 as affected by NPK rates × seed rate interaction in 2015/2016 and 2016/2017 seasons.

NPKFertilizer rate (Kg/fed.)	Seed rates, Grains m^{-2}	Grain protein(%)		Grain carbohydrate(%)	
		2015/2016	2016/2017	2015/2016	2016/2017
$N_{15}P_{7.5}K_{12}$	100	12.61 gh	13.53 k	70.12 a	70.27 b
	150	13.56 f	14.27 hi	70.14 a	71.14 a
	200	14.31 de	14.57 gh	70.15 a	69.90 c
	250	11.92 i	13.88 j	70.18 a	69.81 c
$N_{30}P_{15}K_{24}$	100	13.50 f	13.94 ij	68.69 b	69.76 c
	150	14.38 de	14.62 g	68.57 b	69.67 c
	200	14.63 cd	15.63 e	68.27 c	69.68 c
	250	12.35 h	13.94 ij	68.63 b	69.84 bc
$N_{45}P_{22.5}K_{36}$	100	14.21 e	16.01 d	68.60 b	68.92 d
	150	14.41 de	16.29 d	68.26 c	68.90 d
	200	14.95 c	16.87 c	68.27 c	68.76 d
	250	12.78 g	15.00 f	68.65 b	69.04 d
$N_{60}P_{30}K_{48}$	100	16.31 a	18.07 b	66.94 d	59.05 g
	150	16.51 a	18.19 b	66.22 e	60.60 e
	200	16.65 a	18.54 a	66.14 e	59.79 f
	250	15.40 b	15.55 e	66.31 e	60.43 e
$LSD_{0.05}$		0.41	0.34	0.29	0.44

Effect of Interaction on some grain quality traits

The interaction between NPK fertilizer rates and seeding rates effect on all studied quality traits was not significant except, on grain protein and carbohydrates contents in 2015/16 and 2016/17 seasons.

Grain protein content

As shown in table 7, the accumulation of grain protein was significantly influenced by interaction between NPK fertilizer rates and seeding rates in 2015/16 and 2016/17 seasons. It is obvious from these results that increasing NPK fertilizer rate up to $N_{60}P_{30}K_{48}$ significantly increased grains protein content (%) at different seeding rates. Results showed that the highest value of grain protein content (16.65 and 18.54%) was obtained when applied high rate of NPK ($N_{60}P_{30}K_{48}$) with seeding rate (200 grains m^{-2} or 44 kg $feddan^{-1}$) followed with seeding 150 or 100 seeds/m^2 during both seasons, respectively. however the lowest grain protein content (11.92 and 13.53 %) was produced when $N_{15}P_{7.5}K_{12}$ rate was applied to plots seeded with 250 grains m^{-2} (55 kg $feddan^{-1}$) in the first season or 100 seeds m^{-2} (22 kg $feddan^{-1}$ in the second one table 7.

Grain carbohydrate content

Carbohydrate percentage was significantly respond by NPK combinations and seeding rates interaction during 2015/16 and 2016/17 seasons table 7. The results explained there are negative relationship between the carbohydrate content and increasing NPK rates at various seeding rates during both seasons table 9. In the first season, the highest values of grain carbohydrate (~ 70.00 %) was observed when applied lowest rate ($N_{15}P_{7.5}K_{12}$) with all seeding rates (100, 150, 200 and 250 grains m^{-2}). However, the lowest grain carbohydrate contents (~ 66.00 %) were obtained from plants fertilized with $N_{60}P_{30}K_{48}$ rate and seeded with 150, 200 or 250 grains m^{-2} table 7.

In 2016/2017 season, grain carbohydrate content behaved the same trend of the first season where the highest values of grain carbohydrate (71.14 % was observed when applied lowest rate ($N_{15}P_{7.5}K_{12}$) with seeding rate 150 grains m^{-2}). However, the lowest grain carbohydrate content (59.05 %) was obtained from plants fertilized

Table 8: Effect of NPK fertilizer rateson nitrogen use efficiency (NUE) of biological yield (BY), grains yield (GY) and grain protein yield(GPY)of two - rowbarley cv. Giza 128 in 2015/16 and 2016/17 seasons.

Traits	Season	NPK Fertilizer rate				LSD$_{0.05}$
		$N_{15}P_{7.5}K_{12}$	$N_{30}P_{15}K_{24}$	$N_{45}P_{22.5}K_{36}$	$N_{60}P_{30}K_{48}$	
NUE	2015/16	551.3 a	277.5 b	188.2 c	147.8 d	18.71
(BY)	2016/17	389.4 a	201.6 b	136.4 c	105.3 d	11.84
NUE	2015/16	174.7 a	100.6 b	78.6 c	47.5 d	12.18
(GY)	2016/17	144.9 a	72.9 b	56.3 c	37.3 d	3.06
NUE	2015/16	2288.6 a	1381.9 b	1108.2 b	526.4 c	326.6
(GPY)	2016/17	1798.8 b	1016.1d	824.6ef	584.1g	45.17

with $N_{60}P_{30}K_{48}$ rate and seeded with 100 grains /m^2 table 9.

Nitrogen use efficiency parameters

Nitrogen use efficiency in the crop is influenced by N uptake from the soil, N assimilation in the plant and N redistribution from vegetative parts to the grain (Andersson and Holm 2011).

Effect of NPK fertilizer

Data presented in table 8 show that the effect of different rates of NPK on NUE of biological, grains and grain protein yields in 2015/2016 and 2016/2017 season. The differences in NUE of biological, grains and grain protein yields among the four NPK combinations were significant. Results show that increasing N fertilizer rate significantly decreased NUE of biological, grains and grain protein yields in both seasons. The highest NUE of biological yield (551.3 and 389.4) was with $N_{15}P_{7.5}K_{12}$ and the lowest (147.8 and 105.3) in $N_{60}P_{30}K_{48}$ in 2015/16 and 2016/17 seasons, respectively. A similar trend was observed in NUE of grains and NUE of protein. These results are in harmony with those obtained by Abdul Rehman *et al.,* (2011), Li *et al.,* (2013), Haque Ana, *et al.,* (2017) who reported that the NUE of wheat decrease with increasing N fertilization rate. Etesami *et al.,* (2018) showed that cereal × nitrogen interaction, cereal and nitrogen effects were not significant on nitrogen use efficiency.

Table 9: Effect of seeding rate on nitrogen use efficiency (NUE) of biological, grains and grain protein yields (kg/kg) of two - row barley cv. Giza 128 in 2015/16 and 2016/17 seasons.

Traits	Season	Seeding rate*				LSD$_{0.05}$
		S_1	S_2	S_3	S_4	
NUE	2015/16	268.8 c	286.9 b	294.3 b	314.8 a	17.81
(BY)	2016/17	193.8 c	199.5 bc	209.4 b	229.9 a	10.73
NUE	2015/16	90.8 c	99.4 b	108.6 a	102.5 ab	7.235
(GY)	2016/17	73.1 b	80.1 a	84.7 a	73.8 b	5.718
NUE	2015/16	1175.2 c	1372.2 b	1527.4 a	1229.9 c	102.2
(GPY)	2016/17	1068.2 c	1213.4 b	1329.6 a	1055.9 c	89.9

*S_1= 100 grains m^{-2} (22 kg feddan^{-1}), S_2= 150 grains m^{-2} (33 kg feddan^{-1}), S_3 = 200 grains m^{-2} (44 kg feddan^{-1}) and S_4= 250 grains m^{-2} (55 kg feddan^{-1}).

Effect of seed rate

As shown in table 9 significant differences were recorded between seeding rate in NUE of biological, grains and grain protein yields during 2015/16 and 2016/17 seasons. With increasing seeding rate, the biological yield NUE increased. The greatest biology yield NUE (314.8 and 229.9kg/kg) was achieved at 250 grains m^{-2} (55 kg feddan^{-1}). However, NUE of grains and grain protein were significantly increased by increasing seeding rate up to 200 grains m^{-2} (44 kg feddan^{-1}) then tended to decease at 250 grains m^{-2} (55 kg feddan^{-1}). The lowest values of NUE for biological, grains and grain protein yields were recorded at 100 grains m^{-2} table 9.

Interaction effect

The interaction between NPK combinations and seeding rate significantly affected NUE of biological, grains and grain protein yields in 2016/17 seasons and NUE of biological yield in 2015/2016 season table 10. Result in table 10 indicates that the efficiency of applied fertilizer was higher (609.3 Kg/Kg) when the barley crop was planted with 250 grains m^{-2} (55 kg feddan^{-1}) and fertilized by $N_{15}P_{7.5}K_{12}$ rate in 2015/2016 season. However, the lowest NUE of biological yield values were recorded at $N_{60}P_{30}K_{48}$ rate and seeding by 100, 150, 200 or 250 grains m^{-2} in 2015/2016 season. Both NUE of grains and protein yields was not significantly affected by interaction between NPK fertilizer and seeding rate in 2015/2016 season table 10.

In 2016/2017 season, increasing NPK rate significantly decreased NUE of biological, grains and grain protein yields at the same seeding rate. On the other hand, increasing seeding rate significantly increased NUE of biological, grains and grain protein yields at the same rate of NPK mineral fertilizer. These results are in accordance those of Beatty *et al*., (2010) with barley and Haque, *et al.,* (2017) with wheat.

Conclusion

Based on the results of this study, application of different NPK mineral fertilizer combinations and various seeding rates had significant effects on growth, yield, NUE and grain quality of barely. Overall, the results showed that high significant effect on growth, yield and its components, grain quality traits and NUE during both seasons except,

Table 10: Effect of interaction between NPK Fertilizer rate and seeding rate on NUE of biological, grains and grain protein yieldsof two- row barley cv. Giza 128in 2015/16 and 2016/17 seasons.

Traits	Seeding rate*	NPK Fertilizer rate $N_{15}P_{7.5}K_{12}$	$N_{30}P_{15}K_{24}$	$N_{45}P_{22.5}K_{36}$	$N_{60}P_{30}K_{48}$	$LSD_{0.05}$
2015/2016 season						
NUE of biological yield	S_1	493.1 c	263.0 d	180.8 ef	138.3 g	35.6
	S_2	544.6 b	273.7 d	186.4 e	142.6 g	
	S_3	558.2 b	279.5 d	192.2 e	146.9 fg	
	S_4	609.3 a	293.6 d	193.1 e	163.2 efg	
2016/2017 season						
NUE of biological yield	S_1	366.6 b	178.2 d	133.7 ef	96.6 g	21.5
	S_2	371.1 b	188.4 d	133.1 ef	105.1 g	
	S_3	385.3 b	211.6 c	134.2 ef	106.2 g	
	S_4	434.4 a	227.8 c	144.3 e	113.2 fg	
NUE of grains yield	S_1	136.0 b	69.0cd	51.5 e	35.7 f	11.4
	S_2	156.4 a	69.7 cd	56.6 e	37.5 f	
	S_3	157.7 a	80.2 c	62.2 de	38.4 f	
	S_4	129.5 b	72.9 cd	54.9 e	37.6 f	
NUE of grainprotein yield	S_1	1841.1b	961.8de	824.3 ef	645.6 fg	179.2
	S_2	2231.3 a	1018.1d	921.9de	682.3 fg	
	S_3	2299.3 a	1256.5c	1049.9d	712.6 fg	
	S_4	1798.7 b	1016.0d	824.6ef	584.0 g	

*S_1= 100 grains m^{-2} (22 kg $feddan^{-1}$), S_2= 150 grains m^{-2} (33 kg $feddan^{-1}$), S_3 = 200 grains m^{-2} (44 kg $feddan^{-1}$) and S_4= 250 grains m^{-2} (55 kg $feddan^{-1}$

spike length and biological yield. All the studied indicators increased by increasing NPK fertilizer rates. Seeding rate had significant effect on all studied traits during both seasons except, straw yield and harvest index in one season. Increasing seeding rates significantly decreased No. of shoots and spikes m^{-2}, grains weight spike^{1}, spike length and 1000-grains weight, while plant height, straw, grain and biological yields, harvest index, grain protein content, grain carbohydrate content, NUE of grains, NUE of shoot and NUE of biological were increased by increasing seeding rate during both seasons. The interaction NPK fertilizer rates × seeding rates had no significant effect on all studied traits except weight of grain spike^{-1}, grain protein content and grain carbohydrate content.

References

Abd El-Hameed, I.M. (2011). Response of Barley (*Hordeum vulgare* L.) Cultivars to Nitrogen Fertilizer with Sprinkler Irrigation under Sandy Soil Conditions. *Egyptian Journal of Agronomy,* **33(2):** 141-154.

Abd El-Rahman, E.A. Omar (2013). Response of some barley cultivars to sowing date and seeding rate under sprinkler irrigation system in sandy soils. *Journal of Productivity and Development,* **18(2):** 155-173.

Abdel-Lattif, H.M., M.S. Abbas and M.H. Taha (2019a). Effect of Salicylic acid on Productivity and Chemical Constituents of Some Wheat (*Triticum aestivum* L.) Varieties Grown Under Saline Conditions. *The Journal of Animal & Plant Sciences,* **29(4):** 2019, Page: 1054-1064.

Abdel-Lattif, H.M., M.H. Taha and M.M. Atta (2019b). Nitrogen Use Efficiency and Grain Protein of Corn Affected by Low Nitrogen Application. *Egypt. J. Agron.,* **41(1):** pp. 69–78.

Abido, W.A.E. and S.E. Seadh (2015). Compensation inorganic nitrogen fertilizer needs of barley by organic manure. *J. Plant Production, Mansoura Univ.,* **6(2):** 245–259.

Ahmed Karima, R.L. and A.M.A. Hassan (2019). Effect of planting method on barley productivity, water saving and nutrient use efficiency under El-Minia conditions. *Middle East Journal of Agriculture Research ISSN,* 2077-4605, **8(3):** 788-796.

Alazmani, A. (2015). Evaluation of yield and yield components of barley varieties to nitrogen. *International Journal of Agriculture and Crop Sciences,* **8(1):** 52-54.

Ali Heba, H., S.I. Abbas and A. Badawy (2017). Barley Productivity and Protein Content as Effected by fertilization Treatments under Calcareous Soil Conditions. *Alexandria Journal of Agricultural Sciences,* **62(3):** 319-328.

Amanullah (2015). Specific Leaf Area and Specific Leaf Weight in Small Grain Crops Wheat, Rye, Barley and Oats Differ at Various Growth Stages and NPK Source. *Journal of Plant Nutrition,* **38(11):** 1694-1708.

Andersson, A. and L. Holm (2011). Effects of mild temperature stress on grain quality and root and straw nitrogen concentration in malting barley cultivars. *Journal of Agronomy and Crop Science,* **197:** 466–476.

Beatty, P.H., Y. Anbessa, P. Juskiw, R.T. Carroll, J. Wang and A.G. Good (2010). Nitrogen use efficiencies of spring barley grown under varying nitrogen conditions in the field and growth chamber. *Ann. Bot.,* **105:** 1171-1182.

Biruk, G.K.D. (2016). Effect of nitrogen fertilizer rate on grain yield and quality of malt barley varieties in MalgaWoreda, Southern Ethiopia. *Food Science and Quality Management,* **52:** 2224-6088.

Biswanath, D., C.W. Rogers and Xi. Liang (2019). Plant, grain and soil response of irrigated malt barley as affected by cultivar, phosphorus and sulfur applications on an alkaline soil. *Journal of Plant Nutrition,* DOI: 10.1080/ 01904167.2019.1589504.

Black, C.A. (1965). Methods of Soil Analysis. Amer. Soc. of Agron., Madison, Wisconsin, USA. Methods of Soil Analysis. Amer. Soc. of Argon. Madison, Wisconsin, USA.

BMBRI. (2010). Quality factors in malting barley. Publ. 1510. Available at http://www.bmbri.ca/PDF/Quality%20Factors

%20in%20Malting%20 Barley%20-%20May%202010.pdf (accessed 23 Sept. 2010; verified 18 Feb. 2011). A Brewing and Malting Barley Res. Inst., Winnipeg, MB, Canada.

Bricker, B. (1991). MSTATC: A microcomputer program for the design, management and analysis of agronomic research experimentation. Crop and Sci. Dep. MSU East Lansing Mi 48824 USA.

Conley, D.J., H.W. Paerl, R.W. Howarth, D.F. Boesch, S.P. Seitzinger, K.E. Havens, C. Lancelot and G.E. Likens (2009). Controlling eutrophication: Nitrogen and phosphorus. *Science,* **323:** 1014-1015.

Cottenie A., M. Verloo, L. Kiekens, G. Velgh and R. Camerlynch (1982). Chemical analysis of plants and soils, Lab, Anal Agrochem. State Univ. Ghent Belgium, 63.

Edney, M.J., J.T. O'Donovan, T.K. Turkington, G.W. Clayton, R. McKenzie, P. Juskiw, G.P. Lafond, S. Brandt, C.A. Grant, K.N. Harker and E. Johnson (2012). Effects of seeding rate, nitrogen rate and cultivar on barley malt quality. *Journal of the Science of Food and Agriculture,* **92(13):** 2672-2678.

El-Metwally, A.El-M., M.E.R. Mekkei, R.M. Abd El-Salam and H.M. Abo Shama (2018). Effect of Some Mineral and Bio Fertilization Treatments on Yield and Yield Components of Bread Wheat under Two Seeding Rates. *J. Plant Production, Mansoura Univ.,* **9(9):** 733–738.

Etesami, M., A. Biabani, A.R. Karizaki, A. Gholizadeh and H. Sabouri (2018). Nitrogen use efficiency in winter cereals under optimum nitrogen fertilizer rates. *Middle East Journal of Agriculture Research ISSN,* 2077-4605, **7(1):** 132-138.

FAO, Food and Agriculture Organization of the United Nations (2013). Global production of barley. Faostat 2013.

Gomez, K.A. and A.A. Gomez (1984). Statistical Procedures for Agricultural Research. 2nd ed. John Willey and Sons, New York. pp. 97-411.

Hajighasemi, S., A.R. Keshavarz and M.R. Chaichi (2016). Nitrogen fertilizer and seeding rate influence on grain and forage yield of dual-purpose barley. *Agronomy Journal,* **108(4):** 1486-1494.

Haque Ana, Hossain Me, Haque Me, Hasan Mm, Malek Ma, Rafii1 My and Shamsuzzaman Sm (2017). Supplementary response of yield, nitrogen use efficiency and grain protein content of wheat (*Triticum aestivum* L.) Varieties to different nitrogen rates. *Bangladesh J. Bot.,* **46(1):** 389-396.

Herbert, D., P.J. Philipps and R.E. Strange (1971). Determination of Total Carbohydrates. *Methods in Microbiology,* **5:** pp. 290-344.

Jackson, M.L. (1973). Soil chemical analysis prentice Hell of India Private Limited, New Delhi, 929 pp.

Ju, X.T., G.X. Xing and X.P. Chen (2009). Reducing environmental risk by improving N management in intensive Chinese agricultural systems. *Proc. Natl. Acad. Sci. USA,* **106:** 3041-3046.

Kassa, M. and Z. Sorsa (2015). Effect of nitrogen and phosphorus fertilizer rates on yield and yield components of barley (*Hordeum vugarae* L.) Varieties at Damot Gale District, Wolaita Zone, Ethiopia. *American Journal of Agriculture and Forestry,* **3(6):** 271-275.

Kaur, S., N. Kaur, K.H.M. Siddique and H. Nayyar (2016). Beneficial elements for agricultural crops and their functional relevance in defence against stresses. *Arch. Agron. Soil Sci.,* **62:** 905-920.

Kozera, W., B. Barczak, T. Knapowski, F.E. Spychaj and B. Murawska (2017). Reaction of spring barley to NPK and S fertilization. Yield, the content of macroelements and the value of ionic ratios. *Romanian Agricultural Research,* **(34):** 275-285.

Kumar, V. and P. Jha (2017). Influence of nitrogen rate, seeding rate and weed removal timing on weed interference in barley and effect of nitrogen on weed response to herbicides. *Weed science,* **65(1):** 189-201.

McKenzie, R.H., A.B. Middleton and E. Bremer (2005). Fertilization, seeding date and seeding rate for malting barley yield and quality in southern Alberta. *Can. J. Plant Sci.,* **85:** 603–614.

Merrill, A.L. and B.K. Watt (1973). Energy Value of Foods: Basis and Derivation. Agriculture Handbook No. 74, ARS, United States, Department of Agriculture, Washington DC.https://www.scirp.org/(S(vtj3fa45qm1ean45vvffcz55))/reference/ReferencesPapers.aspx?ReferenceID=1769288.

Moll, R.H., E.J. Kamprath and W.A. Jackson (1982). Analysis and Interpretation of Factors Which Contribute to Efficiency of Nitrogen Utilization. *J. the North Carolina Agric. Res. Service, Raleigh,* **6842:** 562-564. Cited after Ahmed and Hassan (2019).

O'Donovan, J.T., T.K. Turkington, M.J. Edney, G.W. Clayton, R.H. McKenzie, P.E. Juskiw, G.P. Lafond, C.A. Grant, S. Brandt, K.N. Harker, E.N. Johnson and W.E. May (2011). Seeding Rate, Nitrogen Rate and Cultivar Effects on Malting Barley Production. *Agronomy Journal,* **103(3):** 709-716.

O'Donovan, J.T., M.J. Edney, M.S. Izydorczyk, T.K. Turkington, P.E. Juskiw, R.H. McKenzie, C.A. Grant, K.N. Harker, W.E. May, E.N. Johnson and E.G. Smith (2016). Effect of seeding date and rate on malting barley (*Hordeumvulgare* L.) quality. *Canadian journal of plant science,* **97(1):** 10-13.

O'Donovan, J.T., T.K. Turkington, M.J. Edney, P.E. Juskiw, R.H. McKenzie, K.N. Harker, G.W. Clayton, G.P. Lafond, C.A. Grant, S. Brandt and E.N. Johnson (2012). Effect of seeding date and seeding rate on malting barley production in western Canada. *Canadian journal of plant science,* **92(2):** 321-330.

Parkinson, J.A. and S.E. Allen (1975). A wet oxidation procedure for the determination of nitrogen and mineral nutrients in biological material. *Commun. Soil science and plant analysis,* **6:** 1-11.

Perrott, L.A., S.M. Strydhorst, L.M. Hall, R.C. Yang, D. Pauly, K.S. Gill and R. Bowness (2018). Advanced agronomic practices to maximize feed barley yield, quality and stand ability in Alberta, Canada. I. Responses to plant density, a plant growth regulator and foliar fungicides. *Agr. J.,* **110(4):** 1447-1457.

Rawashdeh, Y. (2015). Effect of seeding rates and Nitrogen rates on the phonological characteristics and some of the other productive characteristics of barley varieties under rain fed conditions in southern Jordan. *Journal of Plant Production Sciences, Suez Canal University,* **3(1):** 1-7.

Rogers, C.W., G. Hu and R. Mikkelsen (2017). Grain yield, quality and nutrient concentrations of feed, food and malt barley. *Communications in Soil Science and Plant Analysis,* **48:** 2678–86. doi: 10.1080/00103624.

Ryan, J., M. Abdel Monem and A. Amri (2009). Nitrogen fertilizer response of some barley varieties in semi-arid conditions in Morocco. *J. Agric. Sci. Technol.,* **11:** 227-236.

SalamaHeba, H.S.A. (2019). Dual Purpose Barley Production in the Mediterranean Climate: Effect of Seeding Rate and Age at Forage Cutting. *International Journal of Plant Production,* 1-11.

Shah, S.S.M., X. Chang and P. Martin (2017). Effect of nitrogen, phosphorous, potassium, plant growth regulator and artificial lodging on grain yield and grain quality of a landrace of barley. *International Journal of Environment Agriculture and Biotechnology,* **2(4):** 2020-2032.

Shrestha, R.K. and L.E. Lindsey (2019). Agronomic management of malting barley and research needs to meet demand by the craft brew industry. *Agronomy Journal,* **111(4):** 1570-1580.

Steel, R.G.D. and J.H. Torrie (1997). Principles and procedures of statistics: A biometrical approach. 2nd Edition McGraw Hill Book Co. Inc. New York.

Wali, A.M., A. Shamseldin, F.I. Radwan, E.A. El Lateef and N.M. Zaki (2018). Response of barley (*Hordeum vulgare* L.) cultivars to humic acid, mineral and biofertilization under calcareous soil conditions. *Middle East J.,* **7(1):** 71-82.