Influence of varying seeding rates and nitrogen levels on yield and yield components of barley (*Hordeum vulgare* L. cv. Rum) in the semi-arid region of Jordan

A. T. Munir

Einfluss unterschiedlicher Saatdichten und N-Niveaus auf Ertrag und Ertragskomponenten von Gerste (*Hordeum vulgare* L. cv. Rum) in der semi-ariden Region Jordaniens

1. Introduction

Barley is widely grown in the rainfed areas of the arid and semi arid Mediterranean regions where water and N are the main limiting factors affecting agricultural production (MOHAMMAD et al., 1999). Barley is a widely distributed crop that can grow in a wide range of environmental conditions, even in semi-arid areas with 200–350 mm of annual rainfall (COOPER et al., 1987). It is the second most important crop after wheat in Jordan. Grain is used as feed, food, and for malting purposes, while straw provides an important source of roughage for animals particularly in the dry areas. Unfortunately in Jordan, the local grain yield of barley per unit area is far below the international figures. During the period 1985 to 1997, the average harvested area of barley was 52 thousand ha. The average yield was 815 kg ha^{-1} (MINISTRY OF AGRICULTURE, 1997), while the average yield in major regions of the world was about 2650 kg ha^{-1}, therefore, more research is needed to increase the yield of barley. The most important factors responsible for the low productivity are low and poor distribution of rainfall (OWEIS and TAIMEH, 1996), minimal or no use of fertilizer, the planting of low yield cultivars, and improper cultivation practices (HADDAD et al., 1997). Under these condi-

Zusammenfassung

Ein zweijähriger Versuch im nördlichen Jordanien schätzte die Einflüsse unterschiedlicher Saatdichte und verschiedener N-Niveaus auf den Ertrag und die Ertragskomponenten bei Gerste. Eine Saatdichte von 229 Pflanzen pro m^2 erbrachte das maximale Korngewicht pro Pflanze, die größte Zahl von Ährchen pro Pflanze bzw. von Körnern je Ährchen und das maximale Tausendkorngewicht. Bei einer Dichte von 400 Pflanzen pro m^2 war – Dank der größeren Zahl von Pflanzen pro Flächeneinheit – der maximale Ertrag von 1.753,3 kg/ha zu erzielen. Unter den Stickstoffstufen waren das höchste Korngewicht und der höchste Kornertrag bei 45 kg N/ha zu erzielen. Es ist außerdem zu folgern, dass noch Chancen existieren, um die Saatdichte und die Stickstoffversorgung zu steigern, um das maximale Potenzial der untersuchten Sorten auszuschöpfen.

Schlagworte: Kornertrag, Dünger, Ernteindex, Wasserstress, Ertragskompensation.

Summary

A 2-year study was conducted in northern Jordan to assess the influences of varying seeding rate and N levels on yield and yield components of barley. Seeding rate of 229 plants m^{-2} produced maximum grain weight $plant^{-1}$, highest number of spikes $plant^{-1}$, grains $spike^{-1}$ and maximum thousand grain weight. Whereas at the density of 400 plants m^{-2}, a maximum yield of 1753.3 kg ha^{-1} was obtained owing to the greater number of plants per unit area. Among N levels, the highest grain weight and grain yield was obtained under 45 kg N ha^{-1}. It is further inferred that there were still chances to increase the seeding rate and N levels to exploit the maximum potential of the studied cultivar.

Key words: grain yield, fertilizer, harvest index, water-stress, yield compensation.

tions, N is considered a key input affecting crop production and might be as crucial as water to growth and N uptake (JARADAT and HADDAD, 1994). As barley constitutes about 60 % of the area devoted to cereals in the low rainfall zone, fertilization has a major potential impact (TURK, 1998). However, other agronomic factors must be considered for efficient and economic production. In Jordan, most of the barley planting is done by hand- broadcasting followed by one pass of a disc harrow, which incorporates seed to variable depths. Combined with poor seed quality, it may lead to diverse and erratic stands. To compensate for such losses, farmers generally apply seed at higher rates when broadcasting compared to those used with a drill. In many cases, only the roughest approximations of weight and land areas are used. However, little research has been done using different seeding rates with a drill and has suggested that there was no difference between 80 and 120 kg seed ha^{-1} (JARADAT, 1988). Higher seeding rates, accelerate phenological traits, such as days to flag leaf extension, heading, mid grain filling and maturity (FUKAI et al., 1990; DOFING and KNIGHT, 1992; HENSON and LUKACH, 1992), and are associated with higher tiller and spike numbers m^{-2}, but lower tiller and spike numbers $plant^{-1}$ (MCLOED, 1982; FUKAI et al., 1990; MCDONALD, 1990; DOFING and KNIGHT, 1992). Grain numbers $spike^{-1}$ was found to decrease at higher seeding rates (MCLOED, 1982; DOFING and KNIGHT, 1992). Response to several N levels with different sowing rates for barley has not been considered. Thus, such studies are needed for ascertaining the N and plant density in case of the newly developed high yielding Rum cultivar under the agroclimatic condition of North Jordan. Therefore, the present investigation was undertaken to study the influence of various seed rates and N levels on yield and yield components of barley.

2. Materials and Methods

Field experiments were conducted in the 1996/97 and 1997/98 seasons, at the Jordan University of Science and Technology (JUST) in northern Jordan (32° 34' N latitude; 36° 01' E longitude; and 520 m altitude) on a silt clay soil (very fine montmorillonitic, thermic, typic, chromoxeret) with an organic matter content of 1.6 % and pH of 8.1. Calcium carbonate content is 15 % at the soil surface. Ca is the most dominant extractable cation followed by K, Mg and Na (KHREASAT et al., 1998). The overall climatic conditions of the site are typical Mediterranean weather with average monthly temperature ranging from 3 °C in January to 34 °C in August (JARADAT, 1988). The plot area in both years had been planted to barley during the previous cropping year. Respective values for nitrate-N were 2.7 and 2.1 PPM. According to criteria for dry land soils in the region (RYAN and MATAR, 1990), soils were deficient in N and barley is likely to respond to fertilizer application. As a standard procedure for such trials, and in line with farmers' practice, the site was tilled with a disc harrow. As P was not a variable, triple super phosphate was added at 40 kg $P_2 0_5$ ha^{-1}. N was applied as Urea (46 % N) half at the time of sowing and the other half was applied at onset of stem elongation (appearance of terminal spike). The experiment was laid out in split plot design keeping seeding rate as main treatment (R1 = 229, R2 = 286, R3 = 343 and R4 = 400 plants m^{-2}) and N levels (0, 15, 30 and 45 kg ha^{-1}) as sub-treatment in three replications). The test crop was a six row barley cv. Rum, a variety produced in CIMMYT (Centro Internacional de Mejoramiento de Maizy Trigo), characterized by high tillering, high yielding, and drought tolerance (AL-BATSH, 1997). Planting was on 18 Nov. (1996) and 21 Nov. (1997). The respective harvest dates were 20 May (1997) and 3 June (1998). Individual plots were 4 by 4 m, separated by 0.5 m buffer area. Weeds were removed by hand as needed. Harvesting was done by hand-sickle. The whole plot measurements of total biological yield were taken. Seed yield was estimated from threshed sub-samples. Thirty spikes from each plot were selected for determining thousand grain weight. The data for each trait were subjected to analysis of variance (main effects and interaction). Where effects were significant at the 0.05 probability level, the least significant difference (LSD) was calculated to determine the significance of differences between the means, using the MSTAT-C computer program (Michigan State University).

3. Results and Discussion

Annual precipitation of the 1996/97 and 1997/98 growing seasons were 248 and 292 mm, respectively. In the first growing season, rainfall was 11 mm lower than the long-term average (237 mm), whereas in the second season was 55 mm higher than the long-term average. No significant interaction between seasons was detected. Therefore, the presented results are means across the two growing seasons.

3.1 Nitrogen Effect

N application had a significant effect on all variables measured.

Grain yield, grain weight spike^{-1}, grain number spike^{-1}, spike length, fertile tillers plant^{-1}, spike m^{-2} and plant height were increased by N application, while the 1000 grain weight and harvest index were decreased. Among various N levels, 45 kg N ha^{-1} (N3), significantly out yielded (3.77 g plant^{-1} and 1674.9 kg ha^{-1}) other levels (N0, N1 and N2), owing to the highest number of spikes plant^{-1} (2.71), spike length (4.61 cm) and number of grains spike^{-1} (47.98) though it had the lowest thousand grain weight (32.55 g). Several researchers have found that an increase in N application generally increases the grain number spike^{-1} (TURK and AL-JAMALI, 1998), spike length (ABD EL-LATIF and SALAMAH, 1982), fertile tillers plant^{-1} (FRANK et al., 1992), spike number m^{-2} (LAUER and PARTRIDGE, 1990), plant height (PENNY et al., 1986), and reduces the 1000 grain weight (NEEDHAM and BOYED, 1976), and harvest index (GARDENER and RATHJEN, 1975).

N had a significant effect on grain yield (Table 1). The increase in yield was directly related to more spikes being produced per plant, longer spikes and higher number of grains per spike (Table 2). At the low N rate (N1), the yield advantage was 32 % over that for the N0, but at the high N rate (N3), the yield advantage was 65 %. It was observed that when an attempt was made to increase one yield component there was a compensatory decrease in others.

The increasing N levels decreased the harvest index as the highest (38.06 %) and lowest (34.88 %) values were obtained under N0 and N3, respectively. The results are in

Table 1: Effect of seeding rate and N level on yield and yield components of barley cv. Rum
Tabelle 1: Einfluss von Saatdichte und N-Niveaus auf Ertrag und Ertragskomponenten von Gerste (cv. Rum)

Fertilizer Level (N kg ha^{-1})		Seeding Rate (plants m^{-2}) R1	R2	R3	R4	Mean
		Grain Yield (kg ha^{-1})				
N0		668.8	922.7	1177.3	1300.1	1017.2
N1		875.1	1244.5	1544.9	1697.2	1340.4
N2		996.4	1434.6	1742.1	1903.7	1519.2
N3		1075.7	1596.2	1915.9	2112.1	1674.9
Mean		904.0	1299.5	1595.0	1753.3	
	R	35.24*				
LSD	N	31.75**				
(P≤0.05)	RXN	NS				
		Grain Weight (g plant^{-1})				
N0		2.83	2.06	1.96	1.84	2.17
N1		3.06	3.05	3.05	2.79	3.00
N2		3.71	3.58	3.49	3.19	3.49
N3		3.88	3.81	3.76	3.64	3.77
Mean		3.37	3.12	3.07	2.86	
	R	0.45*				
LSD	N	0.31*				
(P≤0.05)	RXN	NS				
		Thousand grain weight (g)				
N0		35.72	35.38	34.86	33.97	34.98
N1		37.11	35.79	34.91	31.86	34.92
N2		34.13	33.85	33.43	30.97	33.10
N3		33.66	32.88	32.86	30.81	32.55
Mean		35.16	34.48	34.02	31.90	
	R	0.57*				
LSD	N	0.61*				
(P≤0.05)	RXN	NS				

R1, R2, R3 and R4 indicate seeding rates of 229, 286, 343 and 400 plants m^{-2}, respectively.
N0, N1, N2 and N3 indicate nitrogen application rates of 0, 15, 30 and 45 kg N ha^{-1}, respectively.
* and * * indicate significant contrasts at $P \leq 0.05$ and $P \leq 0.01$, respectively. NS = Not significant contrast

Table 2: Mean performance of plant height, grain spike^{-1}, harvest index, spike length, fertile tiller plant^{-1} and spike m^{-2} as affected by seeding rate and levels of N on barley cv. Rum

Tabelle 2: Mittelwerte der Leistungsmerkmale Pflanzenlänge, Körner pro Ähre, Ernteindex, Ährenlänge, fruchtbare Bestockungstriebe pro Pflanze, Ähren pro m² in Abhängigkeit von Saatdichte und N-Niveau bei Gerste (cv. Rum)

Treatment		Plant Height (cm)	Grain Spike^{-1}	Harvest Index	Spike Length (cm)	Fertile Tiller Plant^{-1}	Spike m^{-2}
Seeding Rate (plants m^{-2})							
R1		73.72	46.24	36.59	4.47	2.33	218
R2		71.75	44.83	36.72	4.35	2.23	336
R3		70.56	44.36	37.79	4.28	2.03	388
R4		67.24	41.61	35.43	4.08	1.43	407
Mean		70.80	44.20	36.63	4.29	2.00	337
Fertilizer Levels (N kg ha^{-1})							
N0		63.55	39.84	38.06	3.86	1.35	181
N1		70.64	43.73	37.25	4.29	1.85	311
N2		73.02	45.86	36.39	4.43	2.10	428
N3		76.06	47.98	34.88	4.61	2.71	637
Mean		70.81	44.35	36.64	4.29	2.00	389
	R	0.37*	1.04*	0.43*	0.12*	0.24*	36
LSD	N	1.23*	0.46*	0.28*	0.08*	0.39*	87
($p \leq 0.05$)	RXN	NS	NS	NS	NS	NS	NS

R1, R2, R3 and R4 indicate seeding rates of 229, 286, 343 and 400 plants m^{-2}, respectively.
N0, N1, N2 and N3 indicate nitrogen application rates of 0, 15, 30 and 45 kg N ha^{-1}, respectively.
* and * * indicate significant contrasts at $P \leq 0.05$ and $P \leq 0.01$, respectively. NS = Not significant contrast

accordance with those of PEARMAN et al. (1978), which suggested that the N application had increased the vegetative growth as compared to reproductive growth.

3.2 Seeding Rate Effect

Seeding rate had a significant effect on all variables measured in both seasons. Grain weight spike^{-1}, 1000 grain weight, plant height, grain number spike^{-1}, spike length and fertile tillers plant^{-1} were negatively related to seeding rate.

As for grain weight per plant, it tended to decrease with increases in seeding rate (Table 1). The lowest seeding rate of 229 plants m^{-2} produced the maximum grain weight plant^{-1} (3.37g), and vice versa. This might be attributed to a higher spikes plant^{-1} (2.33), longer spikes (4.47-cm), more grains spike^{-1} (46.24) and heavier thousand grain weight (34.90g). Reductions in barley grain weights have been associated with increasing seeding rates by DOFING and KNIGHT (1992). The highest (2.33) and the lowest (1.43) number of spikes plant^{-1} was recorded under R1 and R4, respectively. The decrease in spike number plant^{-1} in R4 was attributed to an increased competition among plants for growth factors, which finally reduced the number of effective tillers. Reduction of tillering by increasing seeding rate has been reported previously (MCDONALD, 1990). The seeding rate of 343 plants m^{-2} had significantly higher (37.79 %) harvest index over other rates (Table 2), whereas the minimum (35.43 %) was noted in 400 plants m^{-2}. Therefore the results indicate that a higher harvest index does not necessarily indicate a higher grain yield. The increase in rates up to 334 plants m^{-2} did not affect harvest index adversely but exhibited an increasing trend. However, beyond this level, the harvest index was reduced, which clearly indicates that the translocation of photosynthate towards the sink under the seeding rate of 400 plants m^{-2} was affected adversely, and they were accumulated in other parts of the plant.

On the other hand, plant density, spike density (spikes m^{-2}) and grain yield were directly related to seeding rate. Grain yields increased as seeding rates increased, with highest yields being obtained at 400 plants m^{-2}. The yield increase observed with increases in seeding rate is a function of more spikes being produced as a result of more plants being established. The influence of seeding rate on grain yield was through the increased production of spikes per unit area (Table 2), however, not through the increased production of fertile tillers per plant. This explains why maintaining adequate plant populations is important for maximizing grain yield, given the low number of spikes produced, on average, per plant.

The seeding rates currently used for barley vary with agroclimatic zones such that in the drier areas, the recommended rate (257 plants m^{-2}) (TURK, 1998) are much lower than for wetter areas. Higher rather than lower seeding rates are recommended because they also allow for greater crop competition against weeds (KIRKLAND, 1993).

In general, fertility and seeding rate were directly associated with yield of barley. Thus, this study revealed that using seeding rate of 400 plants m^{-2} combined with 45 kg N ha^{-1} was appropriate for highest grain yield unit $area^{-1}$. It is further inferred that there was still a possibility that further increasing the seeding rate and N levels to exploiting the maximum potential of the cultivar Rum.

References

ABD EL-LATIF, L. I. and G. D. SALAMAH (1982): Response of barley to levels of nitrogen and phosphorus under sandy soil conditions. Annual Agric. Sci. Moshtohor 18, 37–45.

AL-BATSH, J. M. (1997): Effect of organic manure and chemical fertilizer on barley performance at al-Muwagar. M. Sc. Thesis, University of Jordan, Amman, Jordan.

COOPER, P. G. M., P. J. GREGORY, J. D. H. KEATINGE and S. C. BROWN (1987): Effect of fertilizer, variety and location on barley production under rainfed conditions in Northern Syria. 2. Soil water dynamics and crop water use. Field Crop Res. 16, 67–84.

DOFING, S. M. and C. W. KNIGHT (1992): Heading synchrony and yield components of barley grown in subarctic environments. Crop Sci. 32, 1377–1380.

FRANK, A. B., A. BAUER and A. L. BLACK (1992): Effect of air temperature and fertilizer nitrogen on spike development in spring barley. Crop Sci. 32, 793–797.

FUKAI, S., C. SEARLE, H. BAIQUNI, S. CHOENTHONG and M. KYWE (1990): Growth and grain yield of contrasting barley cultivars under different plant densities. Field Crops Res. 23, 239–254.

GARDENER, C. J. and A. J. RATHJEN (1975): The differential response of barley genotype to nitrogen application in Mediterranean-type climate. Aust. J. Agric. Res. 26, 219–230.

HADDAD, N., R. TUTWILER and E. THOMSON (1997): Improvement of crop-livestock integration systems in West Asia and North Africa. ICARDA, Aleppo, Syria.

HENSON, B. K. and J. R. LUKACH (1992): Barley response to planting rate in northeastern North Dakota. N. D. Farm Res. 49, 14–19.

JARADAT, A. A. (1988): An assessment of research needs and priorities for rainfed agriculture in Jordan. Pp. 17–64. Al-Hurria, Press. Irbid, Jordan.

JARADAT, A. A. and N. HADDAD (1994): Analysis and interpretation of Mashreq project findings (1990–1992). Special report: Increased productivity of barley, pasture and sheep (RAB/98/026). ICARDA, West Asia Regional Program, Amman, Jordan.

KHREASAT, S. A., Z. RAWAJFIH and M. MOHAMMAD (1998): Morphological, physical and chemical properties of selected soils in the arid and semi-arid regions Northwestern Jordan. J. Arid Env. 40, 15–25.

KIRKLAND, K. J. (1993): Weed management in spring barley (*Hordeum vulgare)* in the absence of herbicide. J. Sust. Agric. 3, 95–104.

LAUER, J. G. and J. R. PARTRIDGE (1990): Planting date and nitrogen rate effect on spring malting barley. Agron. J. 82, 1083–1086.

MCDONALD, G. K. (1990): The growth and yield of uniculum and tillered barley over a range of sowing rates. Aust. J. Agric. Res. 41, 449–461.

MCLOED, C. C. (1982): Effects of rates of seeding on barley sown for grain. N. Z. J. Exp. Agric. 10, 133–136.

MINISTRY OF AGRICULTURE (1997): The annual report. Directorate of economic and political agriculture – statistical department, Amman, Jordan.

MOHAMMAD, M. J., S. ZURAIQI, W. QUAMEH and I. PAPADOPOULUD (1999): Yield response and nitrogen utilization efficiency by drip-irrigated potato. Nut. Cycling in Agroecosystems. 54, 243–249.

NEEDHAM, P. and D. A. BOYED (1976): Nitrogen requirements of cereals. 2. Multilevel nitrogen test with spring barley in southwestern England. J. Agric. Sci 87, 163–170.

OWEIS, T. Y. and A. Y. TAIMEH (1996): Evaluation of a small basin water-harvesting system in the arid region of Jordan. Water Resour. Res. 10, 21–34.

PEARMAN, I., S. M. THOMAS and G. N. THORNE (1978): Effect of nitrogen fertilizer on growth and yield of semidwarf and tall varieties of winter wheat. J. Agric. Sci. (Camb.) 91, 31–45.

PENNY, A., F. V. WIDDOWSON and J. F. JENKYIN (1986): Results from experiments on winter barley measuring the effect of amount and timing of nitrogen fertilisation and some other factors on the yield and nitrogen content on the grain. J. Agric. Sci (Cambridge) 90, 537–549.

RYAN, J. and A. MATAR (1990): Soil Test Calibration in West Asia and North Africa. Proceedings of the third Regional Workshop. 3–9 September 1988, ICARDA, Aleppo, Syria.

TURK, M. A. and A. F. AL-JAMALI (1998): Effect of varying nitrogen supply at different stages on yield and yield components of barley in semi-arid conditions. Crop. Res. 15, 11–20.

TURK, M. A. (1998): Effect of Nitrogen and Phosphorus levels on barley cultivars grown in semi-arid conditions. J. Agron. Crop. Sci. 181, 257–262.

Address of the author

Ass. Professor A. Turk Munir, Department of Plant Production, Jordan University of Science and Technology (JUST), P. O. Box 3030, Irbid, Jordan; e-mail: munatur@just.edu.jo

Eingelangt am 22. Mai 2000
Angenommen am 24. Juli 2001