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Response of Six-Row Barley to Seeding Rate with or without Ethrel Spray in the Absence of Moisture Stress

MUNIR A. TURK, ABDEL RAHMAN M. AL-TAWAHA, OLANI NIKUS AND MOHAMMAD RIFAEE
Department of Plant Production, Faculty of Agriculture, Jordan University of Science and Technology (JUST), Irbid, Jordan

ABSTRACT

A two-year study was conducted in northern Jordan to detect the influence of varying seeding rate and ethrel application on yield and yield components of winter barley. Seeding rate of 120 kg ha^{-1} produced the maximum grain yield ha^{-1}. At this density, it also exhibited the lowest spikes $plant^{-1}$, grains $spike^{-1}$ and thousand grain weight. Whereas at the density of 80 kg ha^{-1}, a minimum yield of 1850 kg ha^{-1} was obtained owing to the lesser number of plants per unit area. Lodging varied across the sowing rates with low lodging occurring at low seeding rate. Grain yield increased for winter barley in cases where ethephon reduced lodging and increased spike m^{-2}. Ethephon effectively reduces lodging in treated winter barley. However, ethephon often reduces grains per spike. Ethephon (2-chloroethel phosphonic acid) application after stem elongation may enhance the grain yield of irrigated barley by increase spike $plant^{-1}$, spike m^{-2} and altering grain filling processes.

Key Words: Ethrel; Ethephon; Grain yield; Barley; Yield components; Moisture stress

INTRODUCTION

Barley (*Hordeum vulgare* L.) is the most widely grown cereal crop in Jordan and other West Asian countries. It is grown mainly as feed for livestock. The productivity of barley crop under rainfed conditions is very low compared to the yield of the crop under irrigated conditions. Water stress has a decisive role in influencing the growth pattern and yield of a crop through effects on nutrient uptake, internal hormonal status during sink development (Donald, 1968) and almost every physiological process in the plant. The plant growth regulator ethephon, [(2 chloroethyl) phosphonic acid], a known source of ethylene which is marketed as ethrel or cerone, effectively reduces plant height and lodging when applied to cereal crops. In cereals, grain yield has been reported to increase when ethephon has prevented lodging (Dahnous *et al.,* 1982; Harms, 1986; Simmons *et al.,* 1988; Boutaraa, 1991). However, positive and negative grain yield responses to ethephon have been reported even when no lodging occurred in comparable untreated barley (Bahry, 1988; Caldwell *et al.,* 1988; Dahnous *et al.,* 1982; Simmons *et al.,* 1988). The ethylene produced upon ethrel application changes the orientation of new cell wall deposition by changing the orientation of the cell's cortical microtubule array. The plant growth regulators: ethylene and gibberellic acid have opposite effects on the orientation of microtubule arrays and hence on the direction of cell expansion in cells of young shoots. Gibberellic acid promotes a net orientation of the microtubule array that is perpendicular to the long axis of the cell. This causes a corresponding cellulose deposition that allows the cells only to elongate producing thin elongated shoots. But if these shoots are treated with ethylene, the microtubule arrays can reorient within an hour to a net longitudinal direction. Cellulose deposition in this direction follows and now the cells expand only laterally producing thick shoots (Alberts *et al.,* 1989) which are lodging resistant (Harms, 1986; Boutaraa, 1991; Brown, 1996).

Cereal grain yield is the product of several components: spikes per area, grains per spike, and grain mass. The net effect of ethephon on grain yield depends on the balance of positive, null, or negative responses of individual yield components to ethephon. Spikes per area may increase, be unaffected, or decrease (Simmons *et al.,* 1988). The most commonly reported responses are increases in spikes per area, and decreases in grains per spike and grain mass. Yield increases when ethephon prevented lodging of cereal crops have been attributed to increased grain mass and/or increased harvestability due to prevention of lodging (Dahnous *et al.,* 1982; Simmons *et al.,* 1988; Brown, 1996). Lodging reduces yield and quality. It makes the harvest of clean grain more difficult. Increased discounts for dirtier grain means lower prices and lost income. Lodging slows the harvest and increases the wear and tear on combines (Brown, 1996). Yield increases with ethephon application in the absence of lodging have been attributed to increased spikes per area (Hill *et al.,* 1982; Bahry, 1988) or spikes per plant (Ramos *et al.,* 1989). Yield decreases with ethephon application have been attributed to reduced grains per spike or reduced grain mass (Bahry, 1988).

Ethephon effectively reduces lodging in treated barley. However, ethephon often reduces grains per spike and grain mass (Moes & Stobbe, 1991b). Reductions in grains per spike may be related to gameticidal properties of ethephon (Hughes, 1975). Increased grain mass was observed when treatment with ethephon prevented lodging in barley (Simmons *et al.,* 1988; Brown, 1996). Causes of decreases in grain mass caused by ethephon application were not known (Moes & Stobbe, 1991b).

Factors which have been observed to influence the type and magnitude of yield component responses to ethephon include cultivar differences, ethephon application rate (Dahnous *et al.,* 1982; Bahry, 1988; Simmons *et al.,* 1988), crop growth stage at time of ethephon application (Caldwell *et al.,* 1988; Brown, 1996), and environment (Simmons *et al.,* 1988). A preliminary experiment we conducted at Irbid, Jordan has shown that ethrel (2-chloroethyl phosohonic acid) decrease the yield of rainfed winter barley. Information is limited for ethephon application and seeding rates of irrigated winter barley in Mediterranean climate. The objectives of this study were to determine effects of ethephon application and seeding rate on agronomic characters of irrigated winter barley in a Mediterranean climate semi arid location**.**

MATERIALS AND METHODS

Field experiments were conducted in the 1999/2000 and 2000/2001 seasons, at the semi arid village of Houfa in the North of Jordan under irrigated conditions. The location has Mediterranean climate of mild rainy winters and dry hot summers. Granular fertilizer DAP (diammonium phosphate 18% N and 46% P_2O_5) at rate of 100 kg ha^{-1} was applied and mixed with soil prior to planting. Split plot designs with three replications were used in both years. The sowing rates (80, 100 and 120 kg ha^{-1}) were randomly assigned to the main plots in each replicate. Ethrel treatments (Ethrel 1500 micrograms L^{-1}) were sprayed at stem elongation and control without ethrel was randomly assigned to each rate plot, representing the sub plot treatments. On application days 27th April 2000 and 28th April 2001 minimum temperatures were 5 and 7^{o}C, and maximum temperatures were 25 and 22^{o}C, respectively**.** The test crop was a six-row barley cv. ACSAD 176. Each sub plot consisted four rows, 30 cm apart and 2 m in length. The seeds were sown by hand on the 1st Nov. 1999 and 2000. The alleys between replicates were 1 m. At harvest, lodging was assessed on a 1-5 scale with 1 = no plants lodged, 2 = 1-25% plants lodged, 3 = 26-50% plants lodged, 4 = 51-75% plants lodged, and 5 = 76-100 5 plants lodged. The measured variables included grain yield (kg ha^{-1}), spikes m^{-2}, grain $spike^{-1}$, plant height (cm), spike length (cm), and days to 50% maturity (day). Data for each trait were analyzed for a randomized complete block design (RCBD) with split–plot arrangement according to Steel and Torrie (1980). Comparisons between means were made using least significant differences (LSD) at 0.05 probability level.

RESULTS AND DISCUSSION

No significant interaction between seasons was detected, probably due to irrigation being used. The main source of yield variation in the Mediterranean region is variation in rainfall. Therefore, the presented results are means across the two growing seasons. Interaction effects of the sowing rates and ethrel applications were, also, not significant in respect of different variables. Lodging in irrigated barley had little or no effect on yields of seed or straw when harvesting was by hand. However, a cutter bar will pass over some of the lodged crop, missing parts of the plants; consequently, increased losses of seed and straw will occur compared to those in an unlodged crop. Lodging varied across the sowing rates with low lodging occurring at low seeding rate. When ethephon was not applied, severity of lodging generally increased as seeding rate increased. Across the growing seasons, ethephon application had a highly significant effect on yield and yield components. The average effect of ethephon on plant growth over seeding rates is summarized in Table I. Grain yields were increased while lodging and plant height was reduced by ethephon applications. Grain yield increased an average of 100 kg ha^{-1} (Table I) while the average reduction in plant height was 5 cm and lodging was reduced from a rating of 3.7 to 1.0. It was demonstrated that ethephon is effective in reducing height and lodging in spring barley, winter barley and barley (Dahnous *et al.,* 1982; Simmons *et al.,* 1988; Moes & Stobbe, 1991b). However, the effect on yield is clear under lodging conditions (Moes & Stobbe, 1991a). Therefore, it is significant in this study that ethephon application after stem elongation increased grain yield. The increment in yield was probably due to increase spike m^{-2} and a prolonged filling period (Table I), which allowed more photosynthate production. The increase in photosynthesis or source strength by ethephon treatment may be an alternative explanation for the yield enhancement by ethephon treatment.

Seeding rate had a significant effect on all variables measured in both seasons. Grain weight $plant^{-1}$, 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 I). The lowest seeding rate of 80 kg ha^{-1} produced the maximum grain weight plant $^{-1}$ (1.25 g) and vice versa. This might be attributed to a higher spikes plant $^{-1}$ (4.5), longer spikes (7.5 cm), more grains $spike^{-1}$ (50.5) and heavier thousand grain weight (41.0 g). Reductions in barley grain weights have been associated with increasing seeding rates by Dofing and Knight (1992). The highest (4.5) and the lowest (3.0) number of spikes plant $^{-1}$ were recorded under 100 and 120-kg ha^{-1}, respectively. The decrease in spike number $plant^{-1}$ in 120 kg ha^{-1} 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).

On the other hand, plant 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 120 kg ha^{-1}. The yield increase observed with increase in seeding rate is a function of more spikes

Table I. Effect of 1500-µL/L ethrel application and seeding rates on yield and yield component of irrigated winter barley

Treatments	Grain yield (kg ha^{-1})	Grain weight (g $plant^{-1}$)	1000 grain weight (g)	Grains $spike^{-1}$	Fertile tillers $plant^{-1}$	Spike m^{-2}
Seeding rate kg ha^{-1}						
80	1850.0 c	1.25 a	41.0 a	50.5 a	4.5 a	393.5 c
100	2125.0 b	0.85 b	40.0 b	47.0 b	3.5 b	452.0 b
120	2225.0 a	0.60 c	38.0 c	43.5 c	3.0 c	473.5 a
LSD α 0.05	97.0	0.10	0.9	3.0	0.4	20.0
Ethrel Treatment						
E0	2016.7 b	0.73 b	38.3 b	49.7 a	3.3 b	429.0 b
E1	2116.7 a	1.06 a	40.7 a	44.3 b	4.0 a	450.3 a
LSD α 0.05	85.0	0.09	0.8	4.2	0.6	21
Interaction	NS	NS	NS	NS	NS	NS

Table II. Effect of 1500-µL/L ethrel application and seeding rates on phenololgical traits of irrigated winter barley

Treatments	Plant height (cm)	Spike length (cm)	Days to 50% maturity	Lodging score
Seeding rate kg ha^{-1}				
80	86.5 a	7.5 a	158.0 a	1.5 c
100	83.5 b	6.7 b	153.0 b	2.5 b
120	80.5 c	5.6 c	148.5 c	3.0 a
LSD α 0.05	3.0	0.8	4.0	0.9
Ethrel Treatment				
E0	86.0 a	7.0 a	150.3 b	3.7 a
E1	81.0 b	6.1 b	156.0 a	1 .0 b
LSD α 0.05	4.0	0.7	5.0	1.0
Interaction	NS	NS	NS	NS

Means followed by the same letter are not significantly different at 5%

being produced as a result of more plants being establishment. The influence of seeding rate on grain yield was through the increased production of spikes per unit area (Table I). However, not through the increased production of fertile tillers per plant. This explains why maintaining adequate plant population is important for maximizing grain yield, given the low number of spikes produced, on average, per plant. High seeding rates promoted phenololgical development, with flag leaf extension and maturity occurring 10 days earlier in the high seeding rate (120 kg ha^{-1}) than in the low (80 kg ha^{-1}) (Table II). Finlay *et al.* (1971) also found those plants from a low seeding rate headed significantly latter than those from higher seeding rates.

In general, ethephon application and seeding rate were directly associated with yield of irrigated barley. Thus, this study revealed that using seeding rate 120-kg ha^{-1} with ethrel treatments (Ethrel 1500 micrograms L^{-1}) sprayed at stem elongation was appropriate for highest grain yield per unit area.

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