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Response of Winter Wheat to Applied N With or Without Ethrel Spray under Irrigation Planted in Semi-arid Environments

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Abstract: Field experiments were conducted during the two growing seasons of 1999/2000 and 2000/ 2001 in Northern Jordan to detect the influence of varying N rates and ethrel application on yield, yield components, and phenolological traits of irrigated winter wheat. Ethrel (2-chlorethyl phosphonic acid) application after stem elongation enhance the grain yield of irrigated winter wheat by increase spikes plant^{-1}, spikes m^{-2}, and altering grain filling processes. When ethrel was applied, lodging in plots that received higher N rates was slightly greater than lodging in plots fertilized at low N rates. Among N rates the highest grain yield was obtained under 120 kg N ha^{-1}.

Key words: Ethrel, wheat, yield components, irrigated, N rates

Introduction

The productivity of winter wheat 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. Nitrogen fertilizers applied to enhance grain yield often result in greater potential for lodging (Marscher, 1986; Hill *et al.*, 1982), consequently, to reduce the threat from lodging, N fertilizer rates were usually restricted. The plant growth regulator ethrel, [(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 ethrel has prevented lodging (Dahnous *et al.*, 1982; Harms, 1986; Simmons *et al.*, 1988; Boutaraa, 1991). However, positive and negative grain yield responses to ethrel 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 ethrel on grain yield depends on the balance of positive, null, or negative responses of individual yield components to ethrel. 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 ethrel 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 ethrel application in the absence of lodging have been attributed to increased spikes per area (Bahry, 1988 and Hill *et al.*, 1982) or spikes per plant (Ramos *et al.*, 1989). Yield decreases with ethrel application have been attributed to reduced grains per spike or reduced grain mass (Bahry, 1988). When plant growth regulators are used, higher rates of N fertilizer than conventionally used in winter wheat can be applied and higher yield goals established without undue risk of lodging. Most research with N and ethrel in small grains has been conducted in humid environments under rainfed conditions.

Information is limited for ethrel application and N fertilization of irrigated winter wheat in semi arid environments. The objectives of this study were to determine effects of ethrel application and N fertilization on agronomic characters of irrigated winter wheat 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. Spilt plot designs with three replications were used in both years. Ethrel treatments (Ethrel 1500 μg L^{-1}) sprayed at stem elongation and control without ethrel was randomly assigned to the main plots in each replicate. On application days 27 April, 2000 and 28 April, 2001 minimum temperatures were 5 and 7 °C, and maximum temperatures were 25 and 22 °C, respectively. N levels (40, 80, and 120 kg ha^{-1}) were randomly assigned to each ethrel treatment plot, representing the sub plot treatments. 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 1.2 ppm. Dry land soils in the region (Ryan and Matar, 1990), soils were deficient in N and cereal is likely to respond to fertilizer application. As is standard procedure for such trials, and in line with farmers' practice, the site was tilled with a disk harrow. As P was not a variable, triple super phosphate was added at 40 kg P_2O_5 ha^{-1}.

The 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 test crop was a winter wheat CV. ACSAD 65. Each sub plot consisted four rows, 30 cm apart and 2 m in length. The seed were sown by hand on the 1st Nov, 1999 and 1st Nov, 2000. The alleys between replicates were 1m. 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 % plants lodged. The measured variables included grain yield (kg ha^{-1}), spikes m^{-2}, grains 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.

Table 1: Effect of 1500 μl L^{-1} ethrel application and N rates on yield and yield component of irrigated winter wheat

Treatments	Grain yield kg ha^{-1}	Grain weight (g $plant^{-1}$)	1000 grain weight	Grains $spike^{-1}$	Fertile tillers $plant^{-1}$	Spike m^{-2}
N kg ha^{-1}						
40	1735.0c	3.6c	38.3a	50.0c	2.5c	378.0c
80	1840.0b	4.2b	35.3b	52.5b	3.7b	403.0b
120	2150.0a	4.7a	32.4c	54.0a	4.5a	468.0a
LSD	0108.0	0.4	01.3	02.0	0.7	019.0
Ethrel treatment						
E0	1866.7b	3.8b	34.3b	57.3a	3.0b	406.7b
E1	1953.7a	4.5a	36.2a	47.3b	4.1a	425.7a
LSD	0081.0	0.5	01.6	06.1	0.9	017.0
Interaction	NS	NS	NS	NS	NS	NS

Means followed by the same letter are not significantly different at 5 % NS = Non Significant

Table 2: Effect of 1500 μl L^{-1} ethrel application and N rates on phenological traits of irrigated winter wheat

Treatments	Plant height (cm)	Spike length (cm)	Days to 50 % maturity	Lodging* score
N kg ha^{-1}				
40	72.5c	6.5c	162.0c	1.5
80	77.0b	7.2b	166.0b	3.0
120	82.0a	7.8a	169.0a	3.0
LSD	04.2	0.5	003.0	-
Ethrel treatment				
E0	80.3a	7.5a	163.7a	3.0
E1	74.0b	6.8b	167.3b	1.3
LSD	05.2	0.6	002.0	-
Interaction	NS	NS	NS	-

Means followed by the same letter are not significantly different at 5 % *, Data statically not analyzed

Results and Discussion

No significant interaction between seasons were detected, probably due to the irrigation being used. The main source of yield variation in the Mediterranean region is variation in rainfall. Therefore, the results (Table 1 and 2) are means across the two growing seasons. Interaction effects of the N levels and ethrel applications were only significant in respect of plant height and lodging score. Lodging in winter wheat has little or no effect on yields of seed or straw when harvesting is 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 in winter wheat is either stem or tiller lodging and occurs from the late grain filling stage onward. It is associated with late rains, strong wind and cracking in clay soils. The direction of lodging is predominantly with the prevailing wind. Plant height was decreased at each N level when ethrel was applied (Table 2). Ethrel shortened wheat an average 6.3 cm compared with untreated plants. The decrease in wheat plant height by ethrel in this study was similar to that obtained in other studies (Dahnous *et al.*, 1982; Hill *et al.*, 1982). Plant lodging was experienced in both growing seasons. Lodging scores in treated plot average 1.3 whereas untreated plots averaged 3.0. When ethrel was applied, lodging in plots that received high N rates was only slightly greater than lodging in plots fertilized at low N rates. When ethrel was not applied, severity of lodging generally increased as N rate increased. Wiersma *et al.* (1986) described a positive relationship between lodging and plant height in winter wheat.

Across the growing seasons, ethrel application had a highly significant effect on yield and yield components. Grain yields were increased by ethrel applications. The increment in yield was probably due to a prolonged filling period, which allowed more photosynthate production. The increase in photosynthesis or source strength by ethrel treatment may be an alternative explanation for the yield enhancement by ethrel treatment. Ethrel application may also have affected sink strength by alteration of dry matter disposition rate, resulting in higher grain weight. Ethrel treated wheat had the highest spikes m^{-2} (Table 1) whereas untreated had the lowest spikes m^{-2} (Table 1). Increase in spikes m^{-2} have been reported for spring barley (Bahry, 1988) and (Moes and Stobbe, 1991). It has been suggested that increased spikes m^{-2} with ethrel treatment was due to prevention of senescence of early tillers (Moes and Stobbe, 1991). Late tillers that appeared on wheat treated with ethrel differed from early tillers in morphology and early growth. Late tillers often emerged by splitting the subtending leaf sheath. Also, as described by Aspinall (1961), the blade on the first leaf of late tillers tended to be short and blunt compared with the first leaf in early tillers. Ethrel applied to wheat caused reductions in grains $spike^{-1}$ This is consistent with the observations of others (Bahry, 1988; Simmons, 1988). The potential of ethrel to induce male sterility in cereal florets (Hughes, 1975; Stoskopf and Law, 1972) provides part of the explanation for the observed reductions in grains $spike^{-1}$, especially in cases where actual reduction were observed for specific shoots. Fewer grains were produced on tillers emerging after ethrel application compared with those that emerged before ethrel application; therefore, grains $spike^{-1}$ for ethrel treated wheat was apparently reduced compared with untreated wheat partly because the former included many late tillers while the latter did not. The apparent increase of grains $spike^{-1}$ with the ethrel application for late appearing shoots compared with untreated wheat was due to increased frequently of appearance and promoted growth of such tillers rather than to a direct increase of grains $spike^{-1}$. Ethrel application increased 1000-grain weight. As the effects on yield the grain weight gain could have been due to higher rates of photosynthatic production and photoassimilate partitioning to the grain, or longer periods of grain fill, or both. In our study, ethrel significantly delay maturity (Table 2) so that a longer filling period could have caused the gain in grain weight. Ethrel treatment prior to heading usually shows little positive effect on grain weight and sometimes decreased it. Thus, it is of interest that an increase in 1000- grain weight was observed in our study.

N application had a significant effect on all variables measured. Grain yield, grain weight $spike^{-1}$, grains number $spike^{-1}$, spike length, fertile tillers $plant^{-1}$ and spikes m^{-2} were directly related to N application, while the 1000 grain weight was decreased. Among various N levels (Table 2), 120 kg N ha^{-1}, significantly out yielded (4.7 g $plant^{-1}$ and 2150 kg ha^{-1}) other levels (40 and 80 N ha^{-1}), owing the highest number of spikes $plant^{-1}$(4.5), spike length (7.8cm) and number of grains $spike^{-1}$ (54) thought it had the lowest thousand weight (32.4g). Several researches have found that an increase in N application generally increases the grains number $spike^{-1}$ (Turk and Al-Jamali, 1998), spike length (Abd El-latif and Salamah, 1982), fertile tillers $plant^{-1}$ (Frank *et al.*, 1992), spikes number m^{-2} (Lauear and Partridge, 1990), and reduces the 1000 grain weight (Needham and Boyed, 1976). Nitrogen fertilizer prolonged the vegetative growing period of irrigated winter wheat and consequently delayed its date of heading. Such a delay was intensified as higher rates of N were applied. The addition of 120-kg N ha^{-1} delayed the formation of the first head by 7 days over the control (Data not presented). These results are in agreement with previous findings (Tisdale and Nelson, 1975).

N had a significant effect on grain yield (Table 1). The increase in yield was always directly related to more spikes being produced per $plant^{-1}$, longer spikes and higher number of grains per spike (Table 1).

In general, ethrel application and N rate were directly associated with yield of irrigated wheat. Thus, this study revealed that using N rate 120 kg ha^{-1} with ethrel treatments (Ethrel 1500 $\mu g\ L^{-}$) sprayed at stem elongation was appropriate for highest grain yield per unit area. When lodging was present ethrel was effective as an anti-lodging agent by reduce lodging and increase harvestable grain yield despite reductions in grain $spike^{-1}$, grain weight, and absolute grain yield.

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