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RESEARCH ARTICLE

EFFECT OF ETHREL SPRAY ON GROWTH AND PHOTOSYNTHETIC CHARACTERISTICS OF MUSTARD (*BRASSIA JUNCEA* L. CZERN AND COSS) CULTIVARS

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ABSTRACT

A field study was conducted at the experimental farm of Aligarh Muslim University, Aligarh on two cultivars of mustard (*Brassia juncea* L. Czern and Coss) namely “Alankar” and “PBM-16” under irrigated and non-irrigated conditions to assess the effect of ethrel (200 μLL^{-1}) on the characteristics of growth and photosynthesis. Ethrel was sprayed at flowering stage [60 days after sowing (DAS)] to mustard crop. Leaf area index, plant dry mass, net photosynthetic rate (P_N), internal CO_2 concentration, stomatal conductance, transpiration rate, carboxylation efficiency, photosynthetic water use efficiency and plant water use efficiency were determined at 80 and 100 days after sowing (DAS). Leaf area index, plant dry mass, net photosynthetic rate, internal CO_2 concentration, stomatal conductance, transpiration rate, carboxylation efficiency, photosynthetic water use efficiency and plant use efficiency were increased by 40.1, 25.0, 30.1, 15.8, 12.9, 9.9, 12.9, 20.8 and 15.1% respectively, by application of 200 μLL^{-1} ethrel.

INTRODUCTION

Ethylene as a plant hormone influences many aspects of plant growth and development (Mattoo and White, 1991; Abeles *et al.*, 1992; Khan *et al.*, 2000). Exogenous application of ethrel increased the leaf area index and photosynthesis in *Brassica juncea* L. under irrigated and non irrigated conditions (Khan 1996; Khan, 1998; Khan *et al.*, 2000; Khan, 2004, Mir *et al.*, 2008; Mir *et al.*, 2009 a,c; Lone *et al.*, 2010). Photosynthesis is the main driving force for biomass accumulation. Among various factors influencing photosynthesis, plant hormones are important in delivering photosynthetic responses by modifying balance between photosynthesis and respiration (Arteca and Dong, 1981; Zerbe and Wild, 1981; Makeev *et al.*, 1992), changes in efficiency of carboxylation (Pua and Chi, 1993; Foroutan-Pour *et al.*, 1997). Studies by Buhler et al. (1978), Grewal and Kolar (1990), Grewal *et al.* (1993), Subrahmanyam and Rathore (1992 a,b), Khan *et al.* (2000), Khan (2004 b), Mir *et al.* (2009 a,c) have shown an increase in photosynthesis with the use of ethrel, while Kays and Pallas (1980) and Rajala and Peltonen-Sainio (2001) have noted decrease. It has been shown that the increase in photosynthesis with ethylene-releasing compounds was due to the increase in chlorophyll per unit leaf area (Grewal *et al.*, 1993) or by greater light interception (Woodrow and Grodzinski, 1989). The objective of this study was to observe the effects of ethrel application on photosynthesis and related physiological traits including dry matter production, leaf area index (LAI), carboxylation efficiency (CE), photosynthetic water use efficiency (WUE) and plant water use efficiency (PWUE) of Indian mustard grown under irrigated and non-irrigated conditions.

MATERIAL AND METHODS

A field experiment was conducted at the experimental farm, Aligarh Muslim University, Aligarh during the water season of 2005-2006 in a completely randomized block designed with three replications. The experiment was carried out under irrigated and non irrigated conditions. The soil at the site was sandy loom with the

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Table.1. Effect of ethrel (200 µLL^{-1}) on leaf area index, plant dry mass, net photosynthetic rate, internal CO_2 concentration and stomatal conductance of mustard cv. Alankar and PBM-16

Treatments	Leaf area index				Plant dry mass (g plant $^{-1}$)				Net photosynthetic rate (µmolCO_2m^{-2}s^{-1})				Internal CO_2 concentration				Stomatal conductance (mole m^{-2} s^{-1})			
	Irrigated		Non-irrigated		Irrigated		Non-irrigated		Irrigated		Non-irrigated		Irrigated		Non-irrigated		Irrigated		Non-irrigated	
	80 DAS	100 DAS	80 DAS	100 DAS	80 DAS	100 DAS	80 DAS	100 DAS	80 DAS	100 DAS	80 DAS	100 DAS	80 DAS	100 DAS	80 DAS	100 DAS	80 DAS	100 DAS	80 DAS	100 DAS
Alankar Contol	3.82	4.11	2.68	2.91	32.51	34.78	26.37	28.33	17.15	15.08	15.49	14.42	273.03	263.43	262.87	253.33	0.44	0.44	0.41	0.40
Alankar Ethrel	4.86	5.35	3.60	4.03	37.78	40.01	32.46	35.63	21.16	19.39	19.20	18.33	312.13	302.20	301.53	290.97	0.48	0.48	0.45	0.44
PBM-16 Contol	3.62	3.67	2.50	2.72	31.17	34.02	25.46	27.53	16.22	14.35	14.23	13.36	267.03	258.07	254.00	245.13	0.42	0.42	0.41	0.39
PBM-!6 Ethrel	4.58	5.11	3.42	3.81	36.18	39.22	31.06	34.17	20.14	18.50	18.61	17.27	301.43	294.43	294.20	283.87	0.46	0.46	0.44	0.42
CD(P=0.05																				
E =	0.21	0.33	0.03	0.17	0.31	0.32	0.29	0.29	0.42	0.26	0.36	0.27	2.96	3.35	3.73	3.41	0.006	0.006	0.007	0.006
CV =	0.20	0.15	0.02	0.11	0.20	0.20	0.19	0.19	0.32	0.22	0.23	0.17	1.87	2.12	2.36	2.16	0.004	0.004	0.005	0.004
EXCV =	0.38	0.40	0.05	0.26	0.44	0.45	0.42	0.45	0.64	0.42	0.50	0.33	3.10	4.13	5.23	5.01	0.007	0.006	0.007	0.005

*DAS= days after sowing; E= ethrel, Cv= cultivar, ExCv= interation between ethrel and cultivar

available N contents 215 kg ha^{-1}. Before sowing 20 litres water for irrigation per m^2 was given to all the plots under both conditions. Uniform seeds of mustard cultivars Alankar and PBM-16 were sown in 10 m^2 plot @ 10 kg ha^{-1}. At seedlings establishment, a plant spacing of 30x50 cm was maintained. In experiment under irrigated conditions, an additional amount of 20 l water for irrigation per m^2 was given to the plots 50 days after sowing (DAS). At flowering stage (60 days after sowing), ethrel (2- chloroethyl phosophonic acid) 200 µLL^{-1} was sprayed @ 6001ha^{-1} together with 0.5% teepol (a surfactant) .In control plants, equal amount of deconized water with 0.5% teepol was sprayed. At 80 (pod filling) and 100 (pod maturity) days after sowing, net photosynthetic rate (P_N), internal $C0_2$ concentration, stomatal conductance, transpiration rate in plants were measured with LICOR- 6200 portable photosynthesis system (Nebraska; USA) at light saturating intensity on a sunny day (at an average photosynthetically active radiation: 1080 µ mol m^{-2} s^{-1}) on fully expanded top leaf of the main axis of four plants. The care was taken to use leaves of the same age for measurement of photosynthesis in control and treated plants. Carboxylation efficiency was calculated as the ratio of photosynthesis to intercellular CO_2 concentration (Farquhar and Sharkey, 1982). Photosynthetic water use efficiency was calculated as the ratio of photosynthesis to stomatal conductance to avoid effects of small differences in vapour pressure between measurements (Von Cammerer and Farquhar, 1981). Plant water use efficiency was computed as the ratio of plant dry mass to transpiration (Van den Boogard *et al*., 1996).

Table.2. Effect of ethrel (200 µLL^{-1}) on transpiration rate, carboxylation efficiency, photosynthetic water use efficiency, plant water use efficiency of mustard cv. Alankar and PBM-16

Treatments	Transpiration rate (Kgm^{-2} day^{-1})				Carboxylation efficiency %				Photosynthetic use efficiency (µmol mol^{-1})				Plant water use efficiency (mg g^{-1})			
	Irrigated		Non-irrigated		Irrigated		Non-irrigated		Irrigated		Non-irrigated		Irrigated		Non-irrigated	
	80 DAS	100 DAS	80 DAS	100 DAS	80 DAS	100 DAS	80 DAS	100 DAS	80 DAS	100 DAS	80 DAS	100 DAS	80 DAS	100 DAS	80 DAS	100 DAS
Alankar Contol	12.79	10.44	11.40	9.28	6.28	5.72	5.89	5.69	39.28	36.48	37.48	35.75	2.54	3.30	2.31	3.04
Alankar Ethrel	13.28	11.02	12.23	10.20	6.77	6.40	6.36	6.30	44.38	43.02	42.99	41.98	2.84	3.63	2.65	3.49
PB M-16 Contol	12.64	10.42	11.32	9.19	6.40	5.56	5.60	5.45	38.32	35.29	35.27	33.96	2.46	3.27	2.25	2.97
PBM-!6 Ethrel	13.20	10.92	12.01	10.07	6.68	6.28	6.32	6.08	44.10	42.37	42.61	40.79	2.74	3.60	2.59	3.39
CD(P=0.05																
E =	0.04	0.03	0.04	0.05	0.19	0.25	0.16	0.12	0.32	0.48	0.53	0.51	0.02	0.02	0.02	0.02
N =	0.03	0.02	0.03	0.03	0.17	0.16	0.10	0.07	0.20	0.30	0.33	0.32	0.01	0.02	0.02	0.01
EXCV =	0.06	0.04	0.06	0.06	0.22	0.30	0.21	0.19	0.45	0.55	0.75	0.72	0.03	0.04	0.03	0.02

*DAS= days after sowing; E= Ethrel, Cv= Cultivar, ExCv= interation between ethrel and cultivar

Leaf area on plant axis was determined by outlining about 10% leaves on graph paper and dry mass of these leaves was recorded. Leaf area per plant was computed by using leaf dry mass per plant and the dry mass of those leaves for which area was estimated (Watson, 1958). Leaf area index was calculated as leaf area in unit land area. Leaf and plant dry masses were determined by drying them in an oven at 80 ^{0}C till constant weight. Data were analyzed statistically using analysis of variance.

RESULTS AND DISCUSSION

Ethrel Spray affected all the parameters in both irrigated and non-irrigated conditions (Table 1 and Table 2) The ethrel spray on Alankar increased the leaf area index, plant dry, mass, net photosynthetic rate, internal CO_2 concentration, stomatal conductance, transpiration rate, carboxylation efficiency, photosynthetic water are efficiency and plant water use efficiency by 27.2, 23.4, 16.2, 14.3, 9.1, 3.8, 6.3, 13.0 and 11.8% over water spray at 80 DAS; 30.2, 15.0, 28.6, 14.7, 9.1, 5.5, 17.9 and 10.0% at 100 DAS under irrigated conditions. The increase in above respective parameters were 34.3, 23.1, 23.9, 14.7, 9.7, 7.3, 8.0, 14.7 and 14.7% by ethrel on Alankar over water spray at 80 DAS; 38.5, 25.0, 27.1, 14.8, 10.0, 9.9, 10.7, 17.4 and 14.8% at 100 DAS under non-irrigated conditions (Table 1 & 2). Treatment ethrel spray on PBM-16 increased the leaf area index, plant dry mass, net photosynthetic rate, internal CO_2 concentration, stomatal conductance, transpiration rate, carboxylation efficiency rate, photosynthetic water use efficiency and plant water efficiency by 26.5, 16.1, 24.2, 12.9, 9.5, 4.4, 9.5, 15.1 and 11.4% over water spray at 80 DAS and 38.5, 15.3, 28.9, 14.1, 9.5, 4.8, 12.9, 20.1 and 10.1% at 100 DAS under irrigated conditions. The increase in above respective parameters at 80 DAS were 36.8, 22.1, 30.1, 15.8, 7.3, 6.1, 12.8, 20.8 and 15.1% and at 100 DAS were 40.1, 24.1, 29.3, 15.8, 7.7, 9.6, 11.5, 20.1 and 14.1% over water spray under non-irrigated conditions. However, cultivar Anlankar showed higher values than PBM-16.

The higher leaf area index due to 200 μLL^{-1} ethrel increased ground cover and had an important influence on water use efficiency reducing soil evaporation and increasing plant dry mass accumulation. The higher leaf area index might be due to ethrel-enhanced ethylene biosynthesis. The higher ethylene evolution led to higher leaf area and thus greater light interception and photosynthesis. The role of ethylene in regulating leaf growth of plants (Abeles *et al*., 1992; Hussain *et al*., 1999; Khan *et al*., 2000; Khan, 2004 a; Mir *et al*., 2009 b), ethylene-induced leaf emergence in cereal seedlings (Ivenish and Kreicberg, 1992), and leaf expansion (Kieber *et al*., 1993; Rodrigues-Pousada *et al*., 1993) has been reported. Photosynthesis is responsive to number of factors, like canopy structure, interception of solar radiation, stomatal conductance and levels of ethylene (Arteca, 1997). The ethrel-enhanced effects on photosynthetic characteristics were mediated through evolved ethylene-induced increase in stomatal conductance. Ethrel is a direct ethylene releasing source when it is applied to plants and elicits response identical to those induced by ethylene gas (Cooke and Randall, 1968; Edgerton and Blanpied, 1968). Taylor and Gunderson (1989) showed a relationship between ethylene-enhanced stomatal conductance and ethylene-enhanced photosynthesis. Earlier Khan (2004a) showed a strong positive correlation between 1-aminocyclopropane carboxylic acid synthase, a rate-limiting enzyme in ethylene biosynthesis, with photosynthesis in mustard cultivars differing in photosynthetic capacity. Observations of Grewal and Kolar (1990), Grewal *et al*. (1993), Subrahmanyam and Rathore (1992 b), Pua and Chi (1993), Khan *et al*. (2000), Khan (2004 b), Mir *et al*. (2009 a,c) and Lone *et al*. (2010) have shown increase in photosynthesis with ethrel spray. Enhanced carboxylation efficiency due to ethrel spray determines the mesophyll effects characterized as a product of CO_2 binding capacity and the electron transport capacity. The effect of ethrel on photosynthesis was also strengthened by the increase in photosynthetic water use efficiency, which has influence on plant water use efficiency and associated with higher Rubisco (Rubisco, ribulose 1,5 bisphosphate carboxylase) activity or rate of electron transport Van den Boogard *et al*. (1995). The higher plant water use efficiency was caused by lower transpiration rate associated with higher leaf area per unit plant dry mass.

CONCLUSION

It is thus concluded that ethrel effects on photosynthesis were through ethylene- induced increase in stomatal conductance and caboxylation efficiency and also through light interception because of increased leaf area. As higher leaf area results in more solar radiations being retained and enhanced photosynthesis and dry mass production which ultimately results in increase in water use efficiency in mustard under irrigated and non- irrigated conditions.

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