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Research Article

Effect of limited irrigation and nitrogen levels on relative water content, transpiration rate, photosynthetic rate and transpirational cooling of Indian mustard [*Brassica juncea* (L.)]

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Abstract : A field investigation was carried out to study the effect of limited irrigation and nitrogen levels on relative water content, transpiration rate, photosynthetic rate and transpirational cooling of Indian mustard. The study indicated that the Indian mustard variety Laxmi maintained higher photosynthetic rate, transpiration rate and more cooler canopy than the variety RH-9304. The higher rate of photosynthetic and transpiration were recorded at flowering as compared to siliqua development stage and irrigation could enhance their rates at both the stages. The nitrogen levels showed variation in leaf photosynthesis rate, transpiration rate, transpirational cooling and relative water content. Application of 120 kg Nha^{-1} recorded highest leaf photosynthesis, transpiration rate, transpirational cooling and relative water content during both the years of study.

Key Words : Limited irrigation, Nitrogen levels, Relative water content, Transpiration rate, Photosynthetic rate, Transpirational cooling, Indian mustard

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INTRODUCTION

The productivity of oil seeds in India is around 935 kgha^{-1} as compared to world level of 1632 kgha^{-1}. A major reason for the low average yield is the cultivation of oil seeds mostly under conditions where soils are both thirty and hungry. Less or no use of plant nutrient is one of the important factors for low productivity of oilseeds. Also, there is an inherent biological limitation for the yield of oil seeds (Mandal *et al.,* 2001). Rapeseed – mustard is the second most important group of oilseed crops in India after groundnut. High yielding varieties of Indian mustard brought break through in yield barriers but the yield potential of these varieties has not been fully exploited and some of the agronomic aspects need to be standardized and optimized for obtaining potential yield per unit area. Tissue water relations, canopy temperature and solar radiation availability alter many agro-physiological response of plants including the diurnal photosynthetic activity which is responsible for overall productivity of the crop (Yadav and Singh, 1981). Since, Indian mustard is mostly raised on conserved soil moisture conditions and in water scarcity areas in India, it becomes very essential to analyse the water relations and micro environment which help to identify the drought resistance (Singh *et al*., 1994). Hence, a study was undertaken to know about different components of plant water relations in Indian mustard varieties under limited irrigation and nitrogen levels.

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EXPERIMENTAL METHODS

Field experiments were conducted during winter season (November – March) of 1999-2000 and 2000-2001 at the Agronomy Research Farm of CCS Haryana Agricultural University, Hisar. The main plot treatments comprised of two India mustard varieties *viz.,* V_1-RH9304, V_2-Laxmi and three irrigation levels *viz.,* I_0-no post sowing irrigation, I_1-One irrigation (60mm) at flowering stage, I_2-one irrigation (60mm) at siliqua development stage and the sub-plot treatments comprised of six nitrogen levels *viz.,* No.-no nitrogen application, N_1-40kg N ha^{-1} and N_2-60 kg N ha^{-1}, N_3-80 kg N ha^{-1}, N_4-100 kg ha^{-1} and N_5-120 kg N ha^{-1}. The experiment was laid out in split- plot design with 3 replications. The soil of the experimental site was sandy loam in texture with pH of 7.5 and 7.6, 0.29 and 0.30 (%) organic carbon, 172 and 168 kg ha^{-1} available N, 16 and 14 kg ha^{-1} available P and 381 and 379 kg ha^{-1} available K during 1999-2000 and 2000-2001, respectively. All nitrogen through urea and phosphorus in the form of SSP were applied at the time of sowing. The crop was sown in rows 30 cm apart on 14th November 1999 and 15th November, 2000, respectively. Post sowing irrigations were of 60mm depth, each given as per requirement of treatments. A rainfall of 19.0 mm in 1999-2000 and 15.0 mm in 2000-2001 was received during the crop growth period. The crop was harvested on 1 April 2000 and 3 April 2001, respectively. The relative water content (RWC) of the leaves were determined as per the method suggested by Bars and Weatherlely (1962) and using the following formula:

$$\text{RWC} = \frac{\textbf{Fresh weight (leaf) – Dry weight (leaf)}}{\textbf{Turgid weight (leaf) – Dry weight (leaf)}}$$

Leaf photosynthetic rate :

A portable infrared gas analyser (IRGA) CI RAR-I/PP system,(U.K.) was used to measure photosynthetic rate during 1999-2000 and 2000-2001. Observations were recorded at the 3rd fully expanded leaf from the top. It was measured between 11.00 to 13.00 hours in the day during flowering and siliqua development state.

Transpiration rate :

The rate of transpiration was measured concurrently with photosynthesis of fully expanded leaf through IRGA between 11.00 to 13.00 hours during both the crop seasons.

Canopy temperature :

The canopy temperature (Tc) and transpirational cooling (canopy minus air temperature, Tc-Ta) were measured between 11.00 to 13.00 hours with the help of infra-red thermometer (Telatemp AG 42) during both the crop seasons.

EXPERIMENTAL RESULTS AND ANALYSIS

The data showing the effects of various treatments on relative water content are presented in Table 1. In General,

Table 1 : Effect of limited irrigation and nitrogen levels on relative water content of Indian mustard

Treatments	Relative water content (%)			
	Flowering stage		Siliqua development stage	
	1999-2000	2000- 2001	1999-2000	2000-2001
Varieties				
V_1	85.89	84.93	84.30	84.23
V_2	87.93	86.97	84.92	84.83
C.D. (P=0.05)	NS	NS	NS	NS
Irrigation schedule				
I_0	86.02	85.00	83.03	83.00
I_1	88.66		87.83	84.06
I_2	86.05	85.02	86.74	86.57
C.D. (P=0.05)	2.15	2.34	1.01	1.00
Nitrogen levels				
N_0	84.24	83.12	82.00	81.92
N_1	86.37	85.16	84.07	84.00
N_2	87.28	86.19	85.11	85.02
N_3	87.57	86.42	85.25	85.16
N_4	87.88	86.78	85.51	85.40
N_5	88.11	88.02	85.73	85.65
C.D. (P=0.05)	0.24	0.35	1.05	1.01

NS=Non-significant

relative water content (RWC) was higher during flowering stage than the siliqua development stage during both the years of study. It was observed from the data that different varieties did not show any significant difference in RWC of leaves. Data showed that irrigational treatments influenced RWC in leaf markedly. Irrigation level I_1 recorded significantly higher RWC value then I0 and I_2 at flowering stage but I_0 and I_2 did not differ significantly. While I_2 level recorded significantly higher RWC than I_1 and I_0 level during siliqua development stage. A perusal of data showed that nitrogen levels increased the RWC in leaf, however, the differences were significant at N_5 level at flowering stage during 1999-2000 and 2000-2001, respectively. During siliqua development stage the differences were significant at N_2 level, however, N_2, N_3, N_4 and N_5 were found to be at par during both the years. Similar observations were also reported by Lal *et al.* (1999).

The rate of transpiration was measured at 50 per cent flowering and siliqua development stage during 1999-2000 and 2000-2001, respectively (Table 2). Irrespective of treatments, transpiration during flowering stage was higher than that recorded at siliqua development stage. It was observed that variety Laxmi (V_2) maintained the highest transpiration rate than the variety RH-9304(V_1) during flowering and siliqua development stage in 1999-2000 and 2000-2001, respectively. A perusal of data showed that irrigational treatments influenced the transpiration rate of Indian mustard markedly. The transpiration rate under unirrigated condition was much lower (1.14 and 1.12. m mole H_2O $m^{-2}s^{-1}$and 0.72. 0.69 m mole H_2O m^{-2} s^{-1}) during flowering and siliqua development stage, respectively. During both the years, increasing nitrogen levels recorded progressive increase in the rate of transpiration. Nitrogen application improved the rooting characteristics, canopy architecture, transpiring leaf surface, stomata regulation which recorded relatively higher transpiration than unfertilized crop. Similar findings were also reported by Qiu *et al.* (2000).

The data pertaining to leaf photosynthetic rate of Indian mustard are presented in Table 2. The variety Laxmi (V_2) recorded higher leaf photosynthetic rate than the variety RH-9304 (V_1) during flowering and siliqua development stage in 1999-2000 and 2000-2001, respectively. During both the stages, the unirrigated crop recorded lesser photosynthesis (12.4, 12.1 at flowering stage and 5.3, 4.8 u mole CO_2 m^{-2} s^{-1} at siliqua development stage) than the irrigated crop in 1999-2000 and 2000-2001, respectively. The highest rate of photosynthesis (15.9 and15.3 µ mole CO_2 m^{-2} s^{-1}) was recorded with I_1 irrigation level at flowering stage during both the years. whereas I_2 level recorded highest rate of photosynthesis (10.2 and 99 µ mole CO_2 m $^{-2}$ s^{-1}) at siliqua development stage. The nitrogen levels also showed variations in leaf photosynthetic rate during both the stages under study. The rate of photosynthesis increased linearly with the increasing levels of nitrogen. Application of 120 kg N ha^{-1} (N_5) recorded highest leaf photosynthetic rate (15.4, 15.1 µ mole CO_2 $m^{-2}s^{-1}$) at flowering stage and (9.7 and 9.4 µ mole CO_2 $m^{-2}s^{-1}$) at siliqua development stage during both the years.

Table 2 : Effect of limited irrigation and nitrogen levels on transpiration rate, photosynthetic rate and transpirational cooling of Indian mustard

Treatments	Transpiration rate (m mole H_2O $m^{-2}s^{-1}$)				Photosynthetic rate (µ mole CO_2 $m^{-2}s^{-1}$)				Transpirational cooling (Tc-Ta^{0}C)			
	Flowering stage		Siliqua dev. stage		Flowering stage		Siliqua dev. stage		Flowering stage		Siliqua dev. stage	
	1999-2000	2000-2001	1999-2000	2000-2001	1999-2000	2000-2001	1999-2000	2000-2001	1999-2000	2000-2001	1999-2000	2000-2001
Varieties												
V_1	1.93	1.89	1.56	1.53	13.5	13.2	8.1	7.8	-2.71	-2.58	-2.44	-2.39
V_2	1.95	1.96	1.62	1.59	13.9	13.4	8.5	8.0	-2.75	-2.64	-2.46	-0.45
Irrigation schedule												
I_0	1.14	1.12	0.72	0.69	12.4	12.1	5.3	4.8	-2.52	-2.39	-1.86	-1.81
I_1	3.53	3.47	1.89	1.86	15.9	15.3	9.4	9.0	-3.11	-3.00	-2.68	-2.67
I_2	1.15	1.14	2.16	2.13	12.8	12.5	10.2	9.9	-2.56	-2.44	-2.81	-2.78
Nitrogen levels												
N_0	1.58	1.55	0.84	0.81	11.1	10.5	5.7	5.1	-2.13	-2.00	-1.79	-1.76
N_1	1.76	1.73	1.26	1.24	12.7	12.3	7.7	7.4	-2.44	-2.32	-2.18	-2.14
N_2	1.91	1.88	1.59	1.56	13.1	12.7	8.6	8.2	-2.73	-2.61	-2.43	-2.40
N_3	2.02	1.97	1.87	1.84	14.7	14.1	9.1	8.8	-2.95	-2.81	-2.61	-258
N_4	2.14	2.11	1.99	1.95	15.1	14.8	9.2	9.0	-3.02	-2.92	-2.78	-2.75
N_5	2.21	2.19	2.01	1.97	15.4	15.1	9.7	9.4	-3.10	-3.01	-2.89	-2.87

The temperature of air and that of leaves were recorded at flowering and siliqua development stage during 1999-2000 and 2000-2001. The difference between canopy (Tc) and air (Ta) temperature which is known as the transpirational cooling is presented in Table 2. In the present study, the mustard variety V_2 maintained more cooler canopy over V_1 during both the years. The differences in transpirational cooling may be attributed to the differences in inherent capacity of plants to absorb and transpire water, leaf area indices and spectrotemporal characteristics of leaves. Similar genotypic variability in transpirational cooling was also reported by Lal *et al*. (1999). A close perusal of data revealed that the unirrigated crop had warmer leaves compared to the irrigated one at both the growth stages. The leaves remained at more cooler state in flowering stage compared to siliqua development stage indicating more transpiration and thereby maintained the leaf canopy less cooler. The data showed that the I_1 level recorded the maximum transpirational cooling at flowering stage whereas I_2 had the maximum transpirationalcooling at siliqua development stage during both the years of study. More water uptake, higher stomatal conductance and thereby higher transpiration all acted positively due to water supply under irrigated condition resulted in more cooling of leaves. Such observations were also made by Stockle and Dugar (1992) and Chaturvedi *et al.* (1999). Transpisrational cooling was more under higher levels of nitrogen. Application of 120 kg N ha^{-1} maintained comparative cooler canopy during both the stages indicating higher transpiration. Under control, nutrient stress reduced the crop growth, produced lower green transpiring surface and reduced conductance, which resulted in lower values of transpirational cooling and giving the leaves more warmer state. The present findings are in agreement with Qiu *et al*. (2000).

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