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EFFECT OF IRRIGATION ON EVAPOTRANSPIRATION, WATER AND ENERGY USE EFFICIENCY OF MUSTARD CROP

Y.S. Ramakrishna, A.S. Rao, R.S. Singh and N.L. Joshi

Central Arid Zone Research Institute, Joddhpur - 342003

ABSTRACT

Performance of mustard crop grown at three levels of irrigation (100% PET, 50% PET and control) was studied for two consecutive seasons in lysimeters to ascertain its optimum water requirements. Mustard crop responded linearly upto 50% PET and thereafter the water use efficiency (WUE) decreased as a result of lower efficiency of the crop to utilise the excess available water for increasing grain production linearly. Both water and energy use efficiencies (EUE) were found to be higher during the flowering, pod formation and seed filling stages of crop. Radiation profile measurements revealed that in mustard crop maintained at potential rate (100% PET), 65% of total incident radiation was absorbed by the crop during vegetative and reproductive stages as against 49% in the control crop which had 70% less leaf area compared to the crop grown at potential rate.

INTRODUCTION

Mustard (*Brassica juncea* L. Czern. & Coss) is widely grown in the Indian arid region. The quantity and frequency of irrigation directly influences the productivity of the crop (Singh and Singh 1959; Yadav 1975; Singh et al. 1985). However, studies on crop sensitivity to water availability during different phenophases indicate that moisture stress at flowering period causes lower yields than at any other stage of the crop (Singh et al. 1970; Singh and Moolani 1972). At Hissar, irrigation of 93 mm, given at a IW/CPE ratio of 0.4 was found better than irrigation at 0.6 ratio (Khan and Agarwal 1985). Optimum frequency and depth of irrigation to mustard under loamy sand were found as 3 irrigations and 21 to 22 cm, respectively (Singh and Yusuf 1979; Prihar and Sandhu 1987).

De wit (1958) showed that the relationship of dry matter (DM) and transpiration are linear till the transpiration of the crop reaches its potential rate. Therefore it becomes essential to establish relationships between yield and evapotranspiration (ET) which would help in planning for efficient management of limited irrigation.

The present study was therefore conducted to assess the response of mustard crop to different levels of evapotranspiration and to analyse its energy balance and advection characteristics under the arid climatic conditions.

MATERIAL AND METHODS

Field experiments were conducted at Central Arid Zone Research Institute, Jodhpur during 1986-87 and 1987-88 rabi season (Oct.-Feb.). The soils of the experimental site were loamy sand, mixed hyperthermic camboorthids, low in organic matter (0.4%), and with moderate amounts of available P (17kg/ha) and available K (190kg/ha). The mustard (cv Pusa bold) was grown under control (three irrigations), 50% PET and 100% PET irrigated conditions. The daily evapotranspiration rates under these three levels of irrigations were measured using gravimetric lysimeters installed in mustard field. Field plots of 2.0 x 2.5 m were made around these lysimeters for crop growth observations. The crop was sown after a pre-sowing irrigation (50 mm). The control crop was given 3 more irrigations of 50 mm each. The 100% PET crop was irrigated daily from 20 days onwards with an amount equal to the ET loss of the previous day. The 50% PET crop was irrigated on every 4th day with an amount equal to 50% of the cumulative PET loss of the previous 4 days. There was 6 mm of rainfall during 1986-87 crop season whereas 11 mm was received during the corresponding period in 1987-88. Initial crop spacing was adjusted to 10 cm in rows of 30 cm each. The growth observations were recorded from a fixed sample of marked plants whereas biomass and leaf area observations were recorded from random sampling areas, collected periodically at 15 days interval.

The net rediation, albedo, soil heat flux, profiles of radiation, humidity and temperatures were recorded at different growth stages at hourly intervals during the day time using Middleton radiation integrators (MPI-200) and Assman psychrometer. Tube solarimeter was used for quantification of radiation interception from the canopy.

The consumptive use, water and energy use efficiencies (WUE, EUE) of the crop at different growth stages, the day time radiation interception by the canopies under the 3 levels of irrigation were computed. The water used by the crop for biomass production during each phase was used for WUE estimation while the total radiation incident on the crop during each phenophase was taken to estimate the EUE during that phase assuming 3990 cal/cm^2 are required for producing one gram of dry matter (Lemon 1969).

RESULTS AND DISCUSSION

Water use and dry matter relationships

The consumptive use was 189, 289 and 364 mm under control, 50% and 100% PET levels during 1986-87 and for the same levels, it was 167, 260 and 327 mm during 1987-88 (Table 1). The variations are due to the difference in the atmospheric conditions in these two years. The crop maintained at 100% and 50% PET rates during the growing season recorded consistently higher dry matter production

Table 1. Water and Energy use efficiencies of mustard

Year	Total biomass (g/m²)	Total consumptive use (mm)	Water use efficiency (kg/ha/mm)	Total solar radiation (cal/m²x10⁴)	Energy use efficiency (%)
CONTROL					
1986-87	679	189	35.9	38925	0.70
1987-88	736	167	44.1	35183	0.84
50% PET					
1986-87	1004 (48)	289	34.7	40068	1.00 (43)
1987-88	1118 (52)	260	43.0	35545	1.26 (50)
100% PET					
1986-87	1141 (68)	364	31.3	40830	1.12 (60)
1987-88	1236 (68)	327	37.8	36269	1.36 (62)

Figures in parenthesis indicate per cent increase w.r.t. control.

at each stage of growth. Similarly, increase in the leaf area from 1000 cm^2 at control to 3220 cm^2 at 100% PET irrigated conditions (Table 2). The dry matter production was higher by 48-52% under 50% PET and by 68% under 100% irrigation over control. This clearly shows that irrigation beyond 50% PET had no linear type of relationship with the total biomass produced. The (WUE) of the crop with respect to total biomass production had established a small decreasing trend from control and 50% PET to 100% PET irrigated conditions (Fig. 1). However the WUE for the grain yield was 5.1, 5.5 and 5.4 kg/ha/mm during 1986-87 and 6.2, 6.8 and

Table 2. Day time energy balance (cal/cm²/day) and radiation penetration into crop canopy

Days after sowing	Leaf area (cm²)	% of radiation penetration	R	G	LE	H	Advection (%)
CONTROL							
30	105	82	149.0	-24.5	-84.8	-39.7	0
60	600	72	143.5	-29.5	-98.7	-15.3	0
78	900	51	203.2	-28.7	-128.8	-45.7	0
95	1000	50	176.8	-23.5	-118.3	-35.0	0
50% PET							
30	150	63	160.9	-20.0	-139.2	1.7	1
60	900	48	156.0	-27.3	-160.1	31.4	20
78	1200		183.9	-27.9	-191.4	35.4	19
95	1290	36	184.7	-34.1	-194.9	44.3	24
100% PET							
30	200	53	163.7	-13.6	-187.9	37.8	23
60	1600	40	152.6	-10.7	-174.0	32.1	21
78	3090	35	153.8	- 7.7	-240.1	94.0	61
95	3220	33	161.1	-22.4	-348.0	209.3	130

R—Net radiation LE—Latent heat flux
G—Soil heat flux H —Sensible heat flux

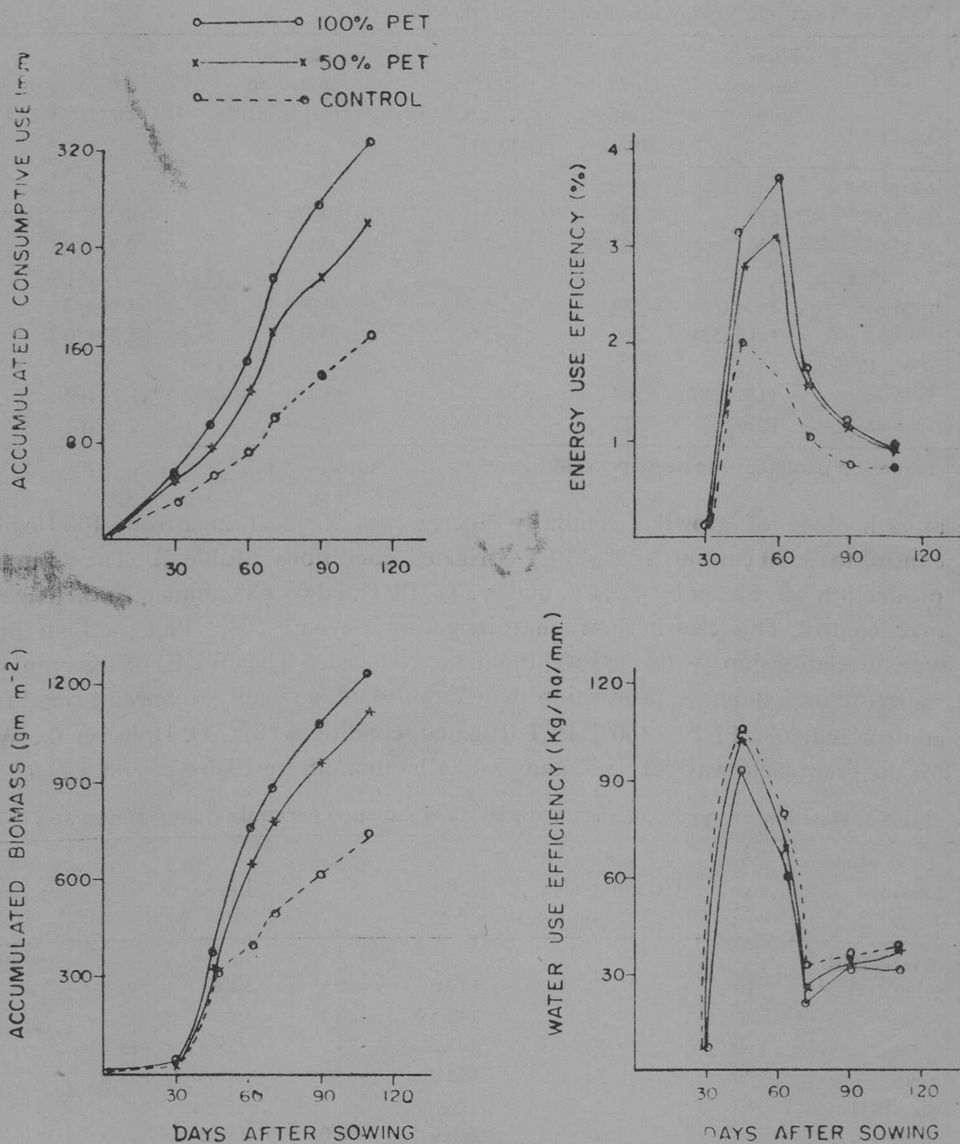

Fig. 1. Consumptive use, Biomass, WUE and EUE of Mustard crop.

6.5 kg/ha/mm during 1987-88 under control, 50% and 100% PET conditions respectively. This clearly indicates that even though control crop had higher WUE in dry matter production, the WUE with respect to grain yield had a linear response of the crop upto 50% PET and thereafter the WUE decreased as a result of lower efficiency of the crop to utilise the excess available water for increasing grain production linearly. During the growing season, the WUE was highest during 35-61 days with peak at 45 days coinciding with the vegetative period. A slight increase in the WUE was also observed again during flowering and pod formation period.

Energy use and biomass relationships

The energy use efficiency (EUE) of the crop increased from 0.70-0.84% in control to 1.12-1.36% under 100% PET irrigated conditions (Table 1). The EUE of the crop was higher by 43-50% at 50% PET and 60-62% at 100% PET conditions than under control conditions.

Energy balance and advection

The crop maintained at potential rate (100% PET) exhibited lower values of soil heat flux (G) due to lower gradients in soil temperature and higher energy utilization in evapotranspiration (Table 2). These features can be attributed to the higher available moisture and homogeneous soil temperature conditions in the top soil layers. The crop grown under control conditions exhibited no advection at any stage because of uniform humidity and evaporative conditions with respect to the surrounding area whereas advection at the rates of 1 to 24% and 21 to130% was recorded (Table 2) under 50% and 100% PET irrigated crop conditions, respectively. Irrigation during the period between 78th day and harvest appears to be uneconomical in improving the plant biomass and also leads to higher evaporation losses of water due to advection as water need of the crop decreases by this period.

Radiation penetration into crop canopy

Radiation profile measurements in mustard using tube solarimeter revealed that radiation absorption by the crop is highest during the vegetative and early reproductive stages of the crop (75-98 days). Amongst the treatments only 33% of the incident radiation in 100% PET and 36% in 50% PET crop could penetrate upto the soil layer compared to 50% of the radiation reaching the bottom under control conditions (Table 2). The irrigated mustard had higher leaf area and hence absorb more radiation. The radiation absorption by the crop was high during the vegetative and reproductive phase of the crop leading to higher EUE especially under irrigated conditions.

REFERENCES

De Wit, C.T. 1958. Transpiration and crop yields. Versl. Landbowkd. Onderz. No. 64 (6) Pudoc., Wagenengen. The Netherlands. 88 p.

Khan, G.M. and Agarwal, S.K. 1985. Effect of crop geometry and irrigation managment on yield, evapotranspiration and WUE of mustard. Indian Journal of Agronomy 30 : 235-240.

Lemon, E.R. 1969. Important micro-c limatic factors in soil water-plant relationships. Modifying the soil and water environment for approaching the agricultural potential of the great plains. Great Plains Agr. Council Publication No. 34. pp. 95-102.

Prihar, S.S. and Sandhu, B.S. 1987. In : Irrigation of field crops-principles and practices. Indian Council of Agricultural Research, New Delhi, p. 84.

Singh, B.P., Yadav, T.B. and Bhola, A.L. 1970. Effect of irrigation and fertility levels on seed yield and quality of raya in Haryana. Telhan Patrika 2 : 25-27.

Singh, G.B. and Singh, D.N. 1959. Irrigation and manurial studies with early and late varieties of rape and mustard. Indian Oilseeds Journal 3 : 109-120.

Singh, G.B. and Moolani, M.K. 1972. Studies on the effect of fertilizer and irrigation levels on water use efficieacy of rai (*Brassica juncea* L.). Proceedings of the symposium 'Soil and Water Management' 1969. Indian Council of Agricultural Research. pp. 323-324.

Singh, S.D. and Yusuf, M. 1979. Effect of water, nitrogen and row spacing on yield and oil content of brown sarson. Canadian Journal of Plant Science 59 : 437-444.

Singh, D.P., Phool Singh, Pratap Singh, Maharaj Singh and Sharma, H.C. 1985. Effect of crop geometry and irrigation management on yield, evapotranspiration and water use efficiency of mustard. Indian Journal of Agronomy 30 : 59-63.

Yadav, J.S.P. 1975 Annual Progress Report. All India Coordinated Research Project on Water Management and Salinity. Central Soil Salinity Research Institute, Karnal.