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Effect of weather on seed yield and radiation and water use efficiency of mustard cultivars in a semi-arid environment

S. Pradhan*, V.K. Sehgal, D.K. Das, A.K. Jain, K.K. Bandyopadhyay, R. Singh, P.K. Sharma

Division of Agricultural Physics, Indian Agricultural Research Institute, New Delhi 110012, India

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ABSTRACT

The date of sowing of Indian mustard (*Brassica juncea*) varies from year to year depending upon the harvesting of previous wet season crop in the northern and north-western part of India, which exposes the mustard crop to variable weather conditions. So an experiment was conducted in Indian Agricultural Research Institute research farm to study the interactive effect of variable weather and cultivars on yield, radiation and water use efficiency of mustard. In this experiment, split plot design was adopted with date of sowing (early, normal and late) as main plot treatment and mustard cultivars (Pusa Gold, Pusa Jai Kisan and Pusa Bold) as subplot treatments. Pooled over the years, mustard seed yield, radiation and water use efficiency was significantly ($p = 0.05$) lower in late sowing compared to early sowing (by 46, 32 and 40%, respectively) and normal sowing (by 44, 26 and 41%, respectively). Early sowing and normal sowing were statistically at par with respect to mustard seed yield and water use efficiency. Among the cultivars, Pusa Jai Kisan and Pusa Bold were statistically at par with respect to seed yield, radiation and water use efficiency whereas Pusa Gold registered significantly lower seed yield, radiation and water use efficiency compared to the cultivars Pusa Jai Kisan (by 55, 23 and 52%, respectively) and Pusa Bold (by 56, 20 and 54%, respectively). There was significant interaction between date of sowing and cultivars with respect to seed yield, radiation and water use efficiency of mustard. From the above study it was concluded that normal or early sowing of the Pusa Jai Kisan or Pusa Bold cultivar may be practiced for achieving higher seed yield, radiation and water use efficiency in the semi arid environment of north and north-western part of India

1. Introduction

Indian mustard (*Brassica juncea*) is the second most important oilseed crop in India after groundnut sharing 27.8% in the India's oilseed economy. The crop occupies an area of approximately 6.90 million hectare with a production of 8.18 million tones (Shekhawat et al., 2012). Mustard crop is highly sensitive to photoperiod and temperature showing quite diverse patterns of growth and development under different sets of environmental conditions (Neog and Chakravarthy, 2005). In India it is mostly grown in northern and north-western part of the country as a *Rabi* (dry winter season) crop after harvesting of *Kharif* (wet rainy season) crop. Solar radiation during winter season of these regions, highly variable and sometimes limited, along with temperature has important bearing on mustard crop growth and development (Kar and Chakravarthy, 2001; Adak et al., 2011a,b).

Under field conditions, the net primary production is found to be linearly related with absorbed or intercepted photosynthetically active radiation (Monteith, 1972, 1977), which in turn depends on leaf area index (LAI) and crop architecture (Plénet et al., 2000). The conversion efficiency of intercepted radiation energy into dry matter is called radiation use efficiency (RUE) (Monteith, 1977). RUE varies not only with species but also with cultivars of the same species. (Yunusa et al., 1993). Farmers of this region are forced to sow the crop in different dates of *Rabi* season depending upon the harvesting of the previous *Kharif* crop. Sowing the crop in different dates exposes the crop to a different weather condition in general and solar radiation and thermal environment in particular. Sowing dates affect crop growth and size of the canopy and ultimately RUE (Giunta and Motzo, 2004). It has also been seen that date of sowing affects water use pattern of mustard, the early sowing requires more water than the late sowing because of crop duration and high initial air temperature. Water is also becoming scarce in these semi arid areas (Chakraborthy et al., 2008) due to rapid urbanization and industrialization. Water use efficiency (WUE) and RUE of a crop are interrelated (Sadras and Connor, 1991). So the optimization of both

* Corresponding author. Tel.: +91 11 25841178; fax: +91 11 25843014.
E-mail address: sanatan28@gmail.com (S. Pradhan).

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WUE and RUE of mustard crop is required in the western and north-western part of India for better utilization of limited water and solar radiation. Keeping these in view, the study was undertaken to investigate the effect of sowing date of three mustard cultivars on yield, radiation and water use efficiency.

2. Materials and methods

2.1. Study area

Field experiments were conducted during *Rabi* (winter) 2010–2011 and 2011–2012 at the experimental farm of the Indian Agricultural Research Institute (IARI), New Delhi (28°37′N Longitude, 77°89′E Latitude and 228.7 m above mean sea level) with mustard as the test crop. The climate is semi-arid with warm summer and mild winter. Summers are long (April–August) with the monsoon setting in between (July–September). The daily weather parameters were collected from the Agromet Observatory of IARI, located about 0.1 km from the experimental plots. The soil is sandy loam (Typic Haplustept) with medium to angular blocky structure, non-calcareous and slightly alkaline in reaction (pH 7.7). The soil (0–30 cm) has bulk density 1.58 Mg/m^3; hydraulic conductivity (saturated) 1.02 cm/h, EC (1:2.5 soil/water suspension) 0.38 dS/m; organic C 5.0 g/kg; total N 0.032%; available (Olsen) P 7.3 kg/ha; available K 281.4 kg/ha; sand, silt and clay, 71.7, 12.0 and 16.3%, respectively. The soil moisture content at saturation was 0.42 m^3/m^3 and at 0.033 MPa (Field Capacity) ranged from 25 to 28% and at 1.5 MPa (Permanent Wilting Point) ranged from 8 to 11% in different layers of 0–30 cm soil depth.

2.2. Experimental design

The experiment was laid out in a split plot design with date of sowing as the main plot and mustard (*B. juncea*) cultivars as subplot factors, replicated thrice. The subplot size was 5 m × 4 m. The date of sowing were D1: early (20th October in 2010–2011 and 14th October in 2011–2012); D2: normal (30th October in 2010–2011 and 31st October in 2011–2012) and D3: late (15th November in 2010–2011 and 16th November in 2011–2012). The mustard cultivars were V1 (Pusa Gold); V2 (Pusa Jai Kisan) and V3 (Pusa Bold). The mustard cultivars were sown at a seed rate of 5 kg/ha with row spacing of 45 cm and plant spacing of 15 cm using a manual seed drill. Nitrogen, phosphorous and potassium were applied as urea, single super phosphate and muriate of potash as basal application at the time of sowing with the recommended dose for the region i.e., 60 kg N/ha, 40 kg P_2O_5/ha and 40 kg K_2O/ha, respectively. The plots were kept weed free. The crop was allowed to grow naturally by allowing the incidence of pest and diseases without any control measures.

2.3. Phenological stages and growing degree days

Phenological stages were recorded by closely following crop growth on every alternate day. The important phenological stages which were recorded are date of sowing, date of 50% emergence, rosette appearance, first flower, 50% flower, pod initiation, seed filling initiation, pod formation end, oil accumulation start, seed filling end, physiological maturity and harvest maturity. The period from 50% emergence to 50% flowering is the vegetative phase and the period from 50% flowering to seed filling end is the reproductive phase. The total crop duration includes the period from sowing to harvest. Phenology of the mustard crop was utilized for fixing the date in the calculation of Total Intercepted Photosynthetically Active Radiation (TIPAR). Growing Degree Day (GDD) for a day was calculated using Eq. (1).

$$GDD = \left(\frac{T_{\max} + T_{\min}}{2}\right) - T_{\text{base}} \quad (1)$$

where $T_{\max}$ is the daily maximum temperature, $T_{\min}$ is the daily minimum temperature and T_{base} is the base temperature. The base temperature of mustard crop was taken as 5 °C (Roy et al., 2005; Adak et al., 2011a,b). Cumulative GDD for a period was calculated by summing up the daily GDD of that period considered.

2.4. Soil moisture storage, evapo-transpiration and Water Use Efficiency (WUE)

Soil moisture content in the profile (0–120 cm) was determined gravimetrically at regular intervals during the crop growth period of 2010–2011 and 2011–2012 to study the distribution and redistribution of the soil water in the profile.

Seasonal Evapo-transpiration (ET) was computed using the field water balance equation (Lenka et al., 2008; Bandyopadhyay et al., 2010a,b) as given below:

$$\text{ET} = (P + I + C) - (R + D + \Delta S) \quad (2)$$

where ET is the seasonal evapo-transpiration (mm), P is the precipitation (mm), I is the irrigation (mm), C is the capillary rise (mm), R is the runoff (mm), D is the deep percolation (mm) and ΔS is change in profile soil moisture (mm).

As the groundwater table was very low (8–10 m depth), C was assumed to be negligible. There was no runoff (R) from the field plots as they were bunded to a sufficient height (40 cm height) and also no case of bund overflow was observed during the period of study. As soil moisture studies were made up to a soil depth of 120 cm and the profile was loamy with a clay loam layer having a high bulk density of 1.71–1.74 Mg/m^3 below 60 cm, deep percolation out of the 120 cm profile (D) was assumed to be negligible (Lenka et al., 2008).

Thus Eq. (2) simplifies to,

$$ET = (P + I) - \Delta S \quad (3)$$

Precipitation data were collected from the meteorological observatory of IARI, which is located about 0.1 km from the experimental plot. Irrigation was supplied through surface irrigation at critical growth stages i.e. flowering and grain filling stage. In each irrigation, an amount of 60 mm water was supplied. The irrigation amount was measured by Parshall Flume. Changes in soil moisture content (ΔS) were calculated by soil moisture sampling by gravimetric method.

Evapo-transpiration production function (ETPF), the relation between mustard seed yield and seasonal evapo-transpiration was linear and was derived as

$$Y = a + b \times ET \quad (4)$$

where a is the intercept and b is the slope of the ETPF.

Water Use Efficiency (WUE) was computed as

$$WUE = \frac{Y}{ET} \quad (5)$$

The net plot (5 m × 4 m) was harvested manually by cutting the plants close to ground after leaving the border rows. The plant samples were dried and weighed for aboveground biomass yield and expressed in kg/ha. Threshing of mustard was done manually and the seed yield was expressed in kg/ha.

Now from Eqs. (4) and (5), it follows that

$$\text{WUE} = b + \frac{a}{\text{ET}} \quad (6)$$