Water Use efficiency and Bio mass Partitioning of Indian mustard (*Brassica juncea* L.) under different environment conditions of Shivalik foot hills

Abstract

A field experiment was conducted during *Rabi* 2018-19 to study the above ground biomass partitioning and water requirement in mustard crop under rainfed as well as irrigated condition. The above ground biomass production was highly affected by thermal environment and water use efficiency of the crop during crop growth period. The total above ground biomass accumulation was found higher in irrigated condition as compared to the rainfed condition. The total above ground biomass was found higher when the crop was sown on October 07, as compared to delayed sowing (October 21 and November 06) under both situations (irrigated and rainfed). The Reference crop evapotranspiration (RCET) was observed higher during PS_1 and PS_3 stages as compared to PS_2 stage due to the effect of other weather elements (*i.e.* maximum and minimum temperature). The total amount of water used by mustard crop was 331.06 mm, 324.90 and 303.65 mm when the crop was sown early, normal and late condition, respectively. The crop water use efficiency (CWUE) of cultivar Pusa Mustard 27 (EJ17) was found higher as compared to the cultivar Pusa Mustard 26 (NPJ113) sown under rainfed and irrigated conditions.

Keywords: *Dates of sowing, Biomass partitioning, irrigated, rainfed, crop water use efficiency, water use.*

Introduction

Studies on biomass production and its partitioning are important aspect of crop management because grain yield depends greatly on the partitioning of photosynthates towards grain filling after anthesis. The yielding ability of a crop is dependent on investment of a greater proportion of biomass in the harvested organs. Quite different processes may limit the yield of different cultivars due to variation in their edaphic and environmental conditions (Willman *et al*., 1987). Synthesis, translocation partitioning and accumulation of photosynthates within the plant are controlled genetically and influenced by the environment (Snyder and Carlson, 1984). The magnitude of maximum biomass accumulation was significantly reduced in late sown crops, which could be partly due to the difference in thermal requirement created by the difference in sowing dates and water use efficiency in different crops (Singh *et al.,* 2002). The efficient use of water in the production of crops needs greater attention owing to the scarcity of irrigation water in our country. The efficient water management technique can save water by decreasing surface runoff so that more water is stored in the soil and water table for future use. Decreasing evaporative losses through fallowing and mulching practices may also reduce water loss. Therefore, present study was undertaken to study the biomass production, it's partitioning and water use of mustard crop as influenced by sowing dates and cultivars.

Materials and Methods

Present study was conducted during *Rabi* season of 2018-19 on mustard cultivars under rainfed and irrigated conditions at the research farm of KVK, Reasi, SKUAST-Jammu. The soil of the research farm is sandy loam in texture and the available nitrogen, phosphorus and potash content in the experimental soil were 214, 13.8 and 129.8 kg/ha, respectively. The treatments comprised of three sowing dates *viz*., October 07 (D_1), October 21 (D_2) and November 06 (D_3) and two cultivars Pusa Mustard 26 (V_1) and Pusa Mustard 27 (V_2) with four replications under rainfed and irrigated conditions to create different crop growth environment. The experiment was laid out in split-split plot design and total treatment combination was 48. The plot size was kept 4 m x 3 m. Only presowing irrigation was applied to the crop sown under rainfed conditions. Under irrigated condition, the irrigation was applied to the crop at 5^{th} leaf, flowering and pod formation stage. The rest of the package and practices were followed as per recommendations. Biomass observations were recorded at three phenophases *viz.*, PS_1: emergence to flower bud initiation, PS_2: flower bud initiation to siliqua formation and PS_3: siliqua formation to maturity. Five plants were randomly selected from each plot and separated into leaves, stem and siliquae. Samples were oven dried at 70^0C for 48 hrs and then weighted. Biomass accumulation in different plant parts was then converted to per square meter (g/m^2).

Potential evapotranspiration (PET) was computed using the Campbell and Diaz (1988) model. The Reference crop evapotranspiration (RCET) for the different sowing dates both under rainfed and irrigated conditions was calculated by adopting the formula used by Kar and Chakravarty (2001). The required meteorological data for these computations were taken from the Agrometeorological observatory of SKUAST-J, main campus Chatha, which is 50 m away from the experimental site. The crop water use at these stages was calculated by using the following formula:

$$\text{Water use} = \text{RCET} \times \text{Kc}$$

Where RCET is Reference crop evapotranspiration and Kc is Crop coefficient (Ram Niwas *et al.* 2002).

The crop water use efficiency (CWUE) for biomass production was worked out at different stages of crop growth and the total CWUE for the whole crop growth period in mustard cultivars in both rainfed and irrigated conditions by using the following formula (Kar and Chakravarty, 2001):

$$\underset{(\text{g/m}^2\text{/mm of water})}{\text{CWUE}} = \frac{\text{Total above ground biomass (g/m}^2\text{)}}{\text{Accumulated crop ET (mm)}}$$

RESULTS AND DISCUSSION

Above ground biomass and partitioning

The division of assimilate (photosynthates) among different parts of the plant termed partitioning, affects both productivity and survival of plant. The partitioning of biomass at different phenophases in Pusa Mustard 27 and Pusa Mustard 26 cultivars influenced by sowing environments under rainfed and irrigated conditions is depicted in Table 1, 2 and 3. The total above ground biomass accumulation was found higher in irrigated condition as compared to the crop grown under rainfed condition. The biomass partitioning at emergence to flower bud initiation (PS_1) of both cultivars was more towards leaves in all treatments as compared to the other plant parts, while at PS_2 stage it was more in stem as compared to leaves and reproductive parts due to more radiation absorption by the plant and more water use as compared to PS_1 (Table 1 & 2). The total biomass accumulation was observed more at siliqua formation to physiological maturity as compared to PS_1 and PS_2 stages. In cultivar Pusa Mustard 26, at PS_1 stage, the mean total biomass production for D_1, D_2 and D_3 were 109.99, 93.55 & 78.25 and 93.08, 81.44 & 75.92 g/m^2, under irrigated and rainfed conditions, respectively (Table 1). It is evident from the data that accumulation of dry matter and its partition to different plant parts was reduced with delay in sowing both under rainfed and irrigated conditions. The reduction in the magnitude of mean biomass accumulation in the normal and late sown crop over the early sowing was about 12 and 18 percent, respectively in rainfed, whereas it was 15 and 29 percent in irrigated condition. Biomass allocation in leaves was maximum at emergence to bud initiation (PS_1) stage followed by stem in both varieties under rainfed as well as irrigated conditions in all dates of sowing. At bud initiation to siliqua formation, highest biomass was recorded in stem followed by leaves and reproductive parts in the same sequence. The highest biomass production was achieved when the crop was sown on 7^{th} October as compared to 22^{nd} October and 06^{th} November both under rainfed and conditions, with the mean values 1028.50, 861.15 & 683.66 and 951.77, 828.35 & 614.89 g/m^2 in cultivar Pusa Mustard 27 under irrigated and rainfed conditions. The reductions of peak biomass production in second and third over I^{st} date was 16.3 and 33.5 percent in irrigated and 13 and 35.4 percent in rainfed condition of cultivar Pusa Mustard 27 . Under irrigated condition, in variety Pusa Mustard 26 , the total mean biomass production among three sowings ranged between 639.19 and 870.08 g/m^2 and the D_3 giving the lowest biomass accumulation. The reduction of biomass production was 8.5 and 26.5 percent in irrigated and 10 & 30.6 percent respectively in rainfed, in D_2 and D_3 over D_1. The percent biomass allocation to leaves was highest at PSI (57%) and it declined thereafter because of the more accumulation of dry matter in stem and then in siliqua. The delay in sowing reduced the total dry matter production and it was the siliquae weight, which has to suffer most due to their poor development in terms of absolute dry weight as well as in terms of percent allocations (Singh *et al* 2002). The delayed sowing reduced the biomass accumulation in different plant parts at all stages among different treatments under both irrigated and rainfed conditions. This indicates that lower night temperature during vegetative phase and higher day temperature during ripening phase are not favourable for mustard grain yield.

Reference crop evapotranspiration

Potential evapotranspiration (PET) at different standard meteorological weeks was computed using the Campbell and Diaz model (1988). The PET is equivalent to reference crop evapotranspiration (Kar and Chakravarty, 2001). The Reference crop evapotranspiration (RCET) was worked out at different standard meteorological weeks for three dates of sowing both under rainfed and irrigated conditions. The results were then pooled for three phenological stages and depicted in Fig 1. Results revealed that the reference crop evapotranspiration ranged from 0.30 to 5.66, 0.30 to 6.02 and 0.36 to 7.05 mm/day in D_1, D_2

and D_3 dates of sowing, respectively under rainfed condition. The total RCET were 530.97, 495.21 and 465.37mm at D_1, D_2 and D_3, respectively in the crop sown under irrigated condition, while in rainfed conditions the RCET values were 504.37, 475.30 and 447.0mm at D_1, D_2 and D_3, respectively. Reference crop evapotranspiration was found higher in irrigated condition as compared to rainfed situation. It was observed more at PS_1 and PS_3 stage as compared to PS_2 stage due to the more number of days taken by these stages as compared to PS_2. The daily reference crop evapotranspiration was found higher (0.7 to 1.5mm/day) when the crop was sown early (D_1) as compared to normal (D_2) and late sown (D_3) during bud initiation to siliqua formation stage (PS_1). The RCET values at PS_1 stage were 199.57, 172.40 & 146.89mm in D_1, D_2 and D_3, respectively under irrigated conditions, while in rainfed conditions; the RCET values were 186.0, 166.60 & 140.0mm at D_1, D_2 and D_3, respectively.

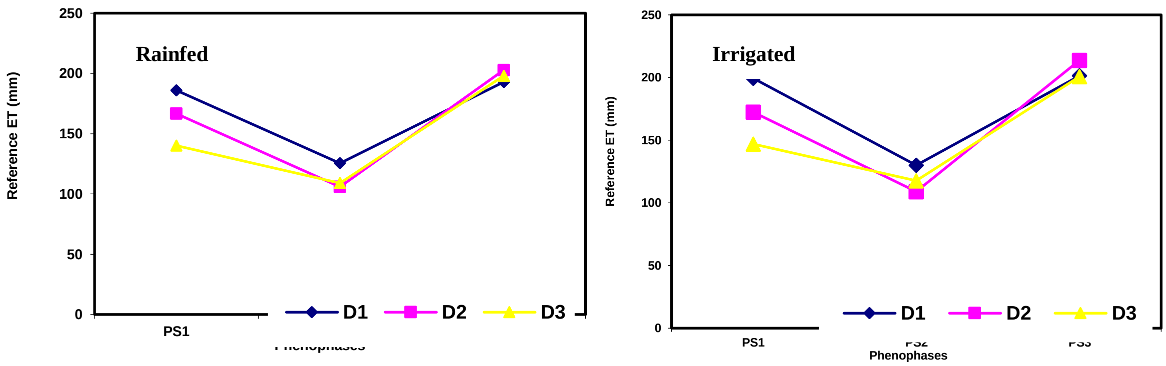

Fig 1. Reference crop evapotranspiration at different stages in mustard crop sown under different environments in both rainfed and irrigated conditions.

Crop water use

The crop water use at different phenological stages sown under irrigated as well as rainfed conditions in different sowing environments is depicted in fig 2. Results revealed that the total crop water use was more under irrigated condition than rainfed in all dates of sowing at different phenological stages. Under rainfed conditions the total amount of water used by the crop was 315.75, 296.81 and 284.35mm, while under irrigated conditions the crop water use was 331.22, 309.21 and 296.66mm for D_1, D_2 and D_3, respectively. The highest amount of water was used by PS_3 stage followed by PS_2 and PS_1 stages of crop growth in all dates of sowing under both irrigated and rainfed conditions. The water use decreased with delay in sowing in both rainfed and irrigated conditions.

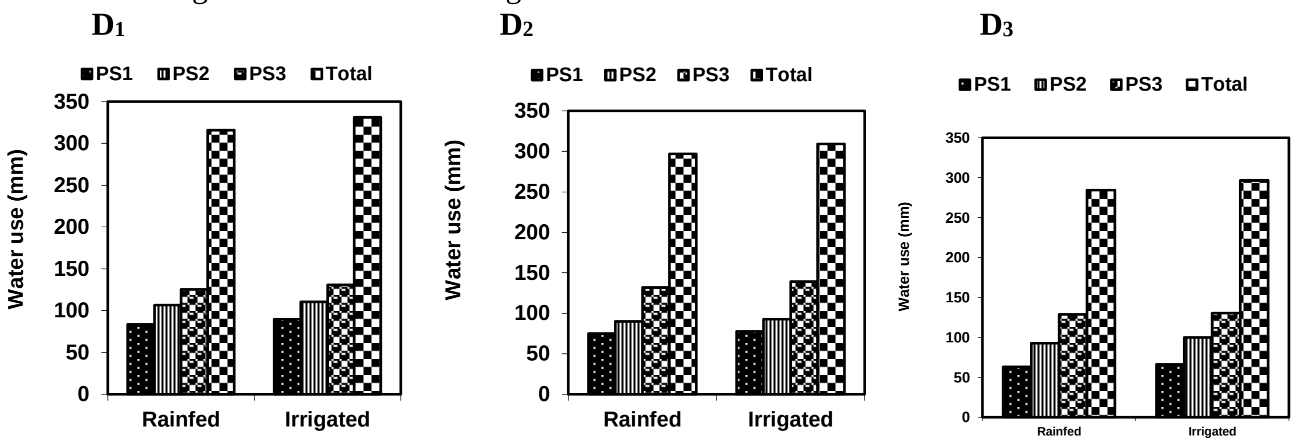

Fig 2. Water use (mm) by mustard crop sown under rainfed as well as irrigated conditions at three phenological stages in different sowing environment.

Crop water use efficiency

The crop water use efficiency, i.e., the amount of biomass produced per unit amount of water utilized (g/m^2/mm of water) was derived for two cultivars in three dates of sowing at different phenophases under rainfed and irrigated conditions (Fig 3 & 4). The crop water use efficiency (CWUE) of cultivar Pusa Mustard 26 ranged from 2.66 to 5.64, 2.62 to 5.15 and 2.57 to 3.47 g/m^2/mm of water at D_1, D_2 and D_3 dates of sowing under rainfed condition (Fig 3). Whereas the cultivar Pusa Mustard 27 exhibits slightly higher values of CWUE at the same stages under the rainfed conditions. The CWUE was nearly same for both cultivars for PS_1 stage, and at PS_2 & PS_3 stages, the same trend was followed. For whole crop period, the total CWUE was 3.75, 3.41 & 3.06 and 4.47, 3.92 & 3.39 g/m^2/mm of water for the cultivars Pusa Mustard 26 and Pusa Mustard 27, respectively in first, second and third dates of sowing, rainfed conditions. While, it was 4.50, 3.87 7 3.06 and 5.32, 4.18 & 3.21 g/m^2/mm of water for cultivars Pusa Mustard 26 and Pusa Mustard 27 , respectively in early, normal and late dates of sowing in irrigated conditions.

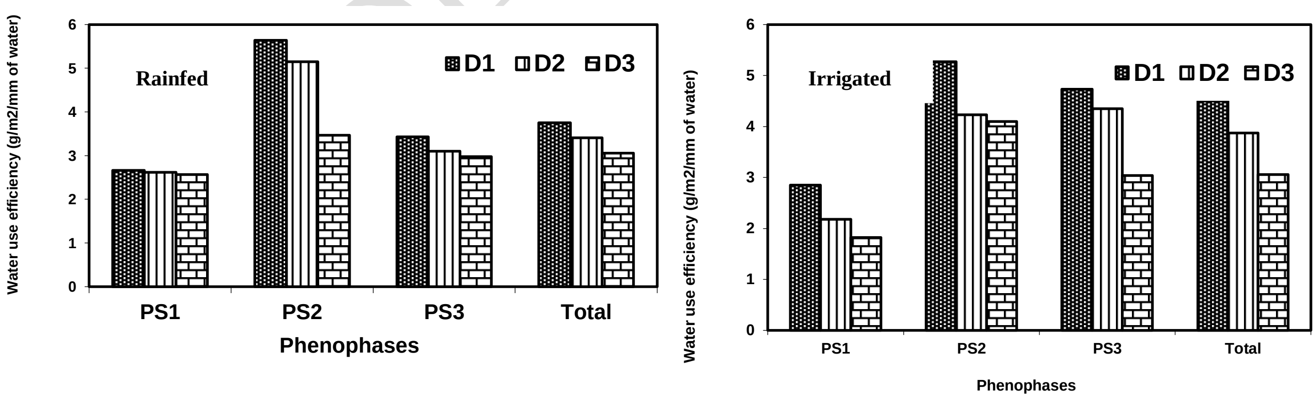

Fig. 3. Crop water use efficiency (g/m^2/mm of water) among different dates of sowings by Pusa Mustard 26 sowed under rainfed as well as irrigated conditions.

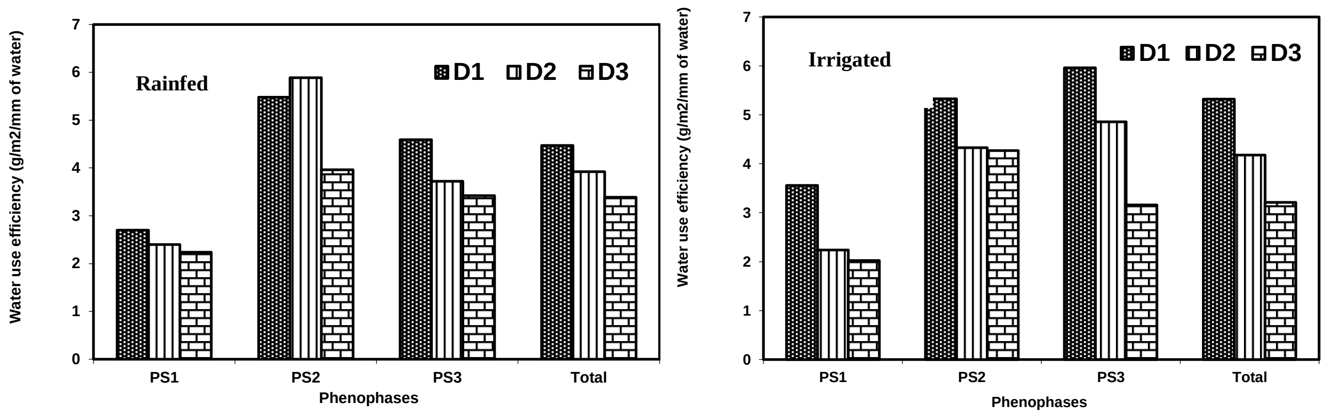

Fig. 4. Crop water use efficiency (g/m^2/mm of water) among different dates of sowings by Pusa Mustard 27 sowed under rainfed as well as irrigated conditions.

Under irrigated and rainfed conditions, both varieties exhibited the highest CWUE during PS_2 stage for all dates of sowing, except that cultivar Pusa Mustard 27 exhibits maximum value of CWUE at PS_3 stage in Ist and 2nd dates of sowing under irrigated conditions (Fig 4). In general, the CWUE values were more in irrigated conditions in both cultivars than in rainfed conditions (Fig. 3 & 4).

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Table1. Partitioning of above ground biomass (g/m^2) into different components of mustard crop at PS I stage.

Treatment	Rainfed			Irrigated		
	Leaf	Stem	Total	Leaf	Stem	Total
Pusa Mustard 26						
Ist sowing	52.35 (56.24)	40.73 (43.76)	93.08	60.37 (54.89)	49.62 (45.11)	109.99
2nd sowing	44.41 (54.53)	37.03 (45.47)	81.44	52.89 (56.54)	40.66 (43.46)	93.55
3rd sowing	40.74 (53.66)	35.18 (46.34)	75.92	46.76 (59.76)	31.49 (40.24)	78.25
Pusa Mustard 27						
Ist sowing	54.07 (57.21)	40.44 (42.79)	94.51	84.06 (61.19)	53.32 (38.81)	137.38
2nd sowing	40.85 (55.07)	33.33 (44.93)	74.18	60.70 (62.84)	35.89 (37.16)	96.59
3rd sowing	37.11 (56.08)	29.06 (43.92)	66.17	56.10 (64.60)	30.74 (35.40)	86.84

The figures in parenthesis show the percentage value

Table2. Partitioning of above ground biomass (g/m^2) into different components of mustard crop at PS II stage.

Treatment	Rainfed				Irrigated			
	Leaf	Stem	Rep. Parts	Total	Leaf	Stem	Rep. Parts	Total
Pusa Mustard 26								
Ist sowing	119.74 (35.60)	198.13 (58.90)	18.52 (5.50)	336.39	135.78 (35.78)	217.75 (57.38)	25.93 (6.84)	379.46
2nd sowing	100.02 (35.47)	165.75 (58.78)	16.20 (5.75)	281.97	115.75 (36.49)	181.10 (57.06)	20.37 (6.45)	317.22
3rd sowing	90.11 (34.93)	155.40 (60.24)	12.47 (4.83)	257.98	105.64 (35.91)	172.10 (58.49)	16.48 (5.60)	294.22
Pusa Mustard 27								
Ist sowing	135.18 (40.84)	179.71 (54.29)	116.11 (4.87)	331.0	155.55 (37.94)	229.61 (56.01)	24.81 (6.05)	409.97
2nd sowing	119.0 (39.18)	170.03 (55.98)	14.72 (4.84)	303.75	125.70 (38.56)	179.60 (55.10)	20.66 (6.34)	325.96
3rd sowing	100.71 (36.80)	160.21 (58.53)	12.78 (4.67)	273.70	115.64 (37.09)	175.48 (56.29)	20.65 (6.62)	311.77

The figures in parenthesis show the percentage value

Table 3. Partitioning of above ground biomass (g/m²) into different components of mustard crop at PS III stage.

Treatment	Rainfed				Irrigated			
	Leaf	Stem	Rep. Parts	Total	Leaf	Stem	Rep. Parts	Total
Pusa Mustard 26								
Ist sowing	51.85 (6.48)	381.45 (47.69)	366.63 (45.83)	799.93	62.74 (7.21)	429.60 (49.37)	377.74 (43.42)	870.08
2nd sowing	32.22 (4.48)	338.46 (47.09)	348.11 (48.43)	718.79	49.63 (6.23)	405.71 (50.96)	340.70 (42.80)	796.04
3rd sowing	29.63 (5.34)	288.32 (51.95)	237.01 (42.71)	554.96	39.25 (6.14)	318.49 (49.83)	281.45 (44.03)	639.19
Pusa Mustard 27								
Ist sowing	66.66 (7.00)	451.81 (47.47)	433.30 (45.52)	951.77	116.02 (11.28)	490.92 (47.73)	421.56 (40.98)	1028.50
2nd sowing	38.51 (4.65)	411.07 (49.63)	378.77 (45.73)	828.35	44.44 (5.16)	440.45 (51.15)	376.26 (43.69)	861.15
3rd sowing	25.93 (4.22)	270.46 (43.99)	318.50 (51.79)	614.89	34.07 (4.98)	314.79 (46.05)	334.80 (48.97)	683.66

The figures in parenthesis show the percentage value