Annals of Plant and Soil Research 15(1): 9-14 (2013)

BIOMASS PARTITIONING AND WATER USE EFFICIENCY OF MUSTARD CULTIVARS SOWN UNDER DIFFERENT ENVIRONMENTS

MAHENDER SINGH, M.K. KHUSHU*, VIKAS GUPTA AND JAI KUMAR

Dry Land Research Sub Station Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu
Rakh Dhiansar, B.Brahmna, Samba-181 133 (Jammu and Kashmir)
Received: September 2012

ABSTRACT

Field experiment was conducted during rabi seasons of 2005-06 at Agromet research farm of SKUAST-J, Chatha, to study the above ground biomass partitioning and water requirement in mustard 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 higher in irrigated condition as compared to the rainfed condition. The total above ground biomass was 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, 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 Bahar was found higher as compared to the cultivar Varuna 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

The study was conducted during *rabi* season of 2005-06 on mustard cultivars under rainfed and irrigated conditions at the research farm of the All India Coordinated Research Project on Agrometeorology, Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu, main campus Chatha (32^0 $39^/$ N, 74^0-$58^/$ E 332 m amsl). The soil of the research farm was 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^{-1}, respectively. The treatments comprised of three sowing dates *viz*., October 07, 2005 (D_1), October 2, 2005 (D_2) and November 06, 2005 (D_3) and two cultivars Varuna (V_1) and Pusa Bahar (V_2) were laid out in split-split plot design with four replications. The plot size was kept 4 m x 3 m. Only pre-sowing irrigation was applied to the crop sown under rainfed conditions. Under irrigated condition, three irrigations were applied to the crop i.e. 1^{st} at 5^{th} leaf, 2^{nd} at flowering and 3^{rd} at pod formation stage. The rest of the package and practices were followed as per recommendations. Biomass observations were recorded at three phenophases PS_1: emergence to flower bud initiation, PS_2: flower bud initiation to siliqua formation and PS_3: siliqua

*All India Coordinated Research Project on Agrometeorology
Corresponding author: drmahendersinghg@gmail.com, msghanghas@yahoo.co.in

formation to maturity. Five plants were randomly selected from each plot and separated into leaves, stem and reproductive parts. 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:

Water use = RCET x 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 adopted by Kar and Chakravarty (2001)

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

RESULTS AND DISCUSSION

Above ground biomass and partitioning

The partition of assimilate (photosynthates) among different parts of the plant termed partitioning, affects both productivity and survival of plant. The data on partitioning of biomass at different phenophases (PS_1, PS_2 and PS_3) in Pusa Bahar and Varuna cultivars influenced by sowing environments under rainfed and irrigated conditions are presented in Table 1, 2 and 3, respectively. 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 and 2). Similar findings were reported by Somayeh *et al.*, (2011). The total biomass accumulation was observed more at siliqua formation to physiological maturity as compared to PS_1 and PS_2. In cultivar Varuna, at PS_1 stage, the mean total biomass production for D_1, D_2 and D_3 were 109.99, 93.55 and 78.25 and 93.08, 81.44 and 75.92 g m^{-2}, under irrigated and rainfed conditions, respectively (Table 1).

Table1: Partitioning of above ground biomass (g m^{-1}) into different components of mustard crop at PS_I stage

Treatment	Rainfed			Irrigated		
	Leaf	Stem	Total	Leaf	Stem	Total
			Varuna			
Ist Sowing (D_1)	52.35 (56.24)	40.73 (43.76)	93.08	60.37 (54.89)	49.62 (45.11)	109.99
2^{nd} Sowing (D_2)	44.41 (54.53)	37.03 (45.47)	81.44	52.89 (56.54)	40.66 (43.46)	93.55
3^{rd} Sowing (D_3)	40.74 (53.66)	35.18 (46.34)	75.92	46.76 (59.76)	31.49 (40.24)	78.25
			Pusa Bahar			
I^{st} Sowing (D_1)	54.07 (57.21)	40.44 (42.79)	94.51	84.06 (61.19)	53.32 (38.81)	137.38
2^{nd} Sowing (D_2)	40.85 (55.07)	33.33 (44.93)	74.18	60.70 (62.84)	35.89 (37.16)	96.59
3^{rd} Sowing (D_3)	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

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 %, respectively. But under rainfed, it was found 15 and 29 % under 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 and 683.66 and 951.77, 828.35 and 614.89 g m^{-1} in cultivar Pusa Bahar under rainfed and irrigated conditions. The reductions of peak biomass production in second and third over I^{st} date was 16.3 and 33.5 % in irrigated and 13 and 35.4 % in rainfed condition of cultivar Pusa Bahar. Under irrigated condition, in variety Varuna, the maximum mean biomass production during PS_3 stage among three sowings ranged between 639.19 and 870.08 g m^{-1} and the D_3 giving the lowest biomass accumulation. The reduction of biomass production was 8.5 and 26.5 % in irrigated and 10 and 30.6 % in D_2 and D_3 over D_1, respectively under rainfed condition. The percent biomass allocation to leaves was highest at PS_1 (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.

Table 2: Partitioning of above ground biomass (g m^{-1}) into different components of mustard crop at PS_2 stage

Treatment	Rainfed				Irrigated			
	Leaf	Stem	Rep. Parts	Total	Leaf	Stem	Rep. Parts	Total
				Varuna				
I^{st} Sowing (D_1)	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
2^{nd} Sowing (D_2)	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
3^{rd} Sowing (D_3)	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 Bahar				
I^{st} Sowing (D_1)	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
2^{nd} Sowing (D_2)	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
3^{rd} Sowing (D_3)	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

Reference crop evapotranspiration

Potential evapotranspiration (PET) at different standard meteorological weeks was computed using the Campbell and Diaz (1988) model. 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^{-1} in D_1, D_2 and D_3 dates of sowing, respectively under rainfed condition. 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. In the second and third dates of sowing, the variation of reference evapotranspiration followed more or less the similar trend. The comparison of (RCET) for the three dates of sowing shows those in the first date of sowing the values were higher in the range of 0.7 to 1.5 mm day^{-1} at PS_2 stage than second and third date of sowing. During other phenological stages, the values were almost comparable for all the three dates of sowing of mustard crop (Fig. 1). The values of RCET were found more at all three stages (PS_1, PS_2 and PS_3) in early sowing (7^{th} October) than normal (21^{st} October) and delayed sowing (6^{th} November) both under rainfed and irrigated conditions. The RCET were 225.72, 172.53 and 137.43mm at D_1, D_2 and D_3, respectively in the crop sown under irrigated condition, while at this stage the RCET were 207.05, 172.60 and 153.55 mm at D_1, D_2 and D_3, respectively.

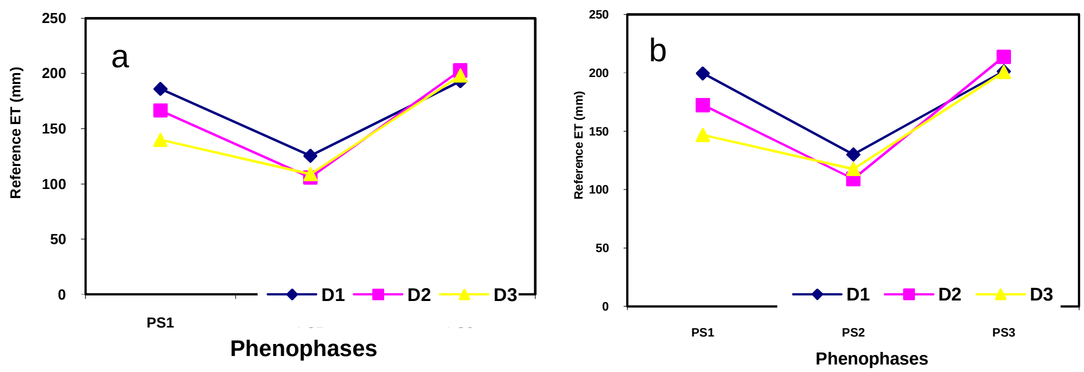

Fig. 1: Reference crop evapotranspiration at different stages of mustard crop sown under a) rainfed and b) irrigated conditions

Crop water use

Crop water use at different growth stages of three dates of sowing under irrigated and rainfed conditions was derived by multiplying the reference evapotranspiration with the crop coefficient at respective growth stages and the result is presented in Fig.2. Under rainfed conditions, the total amount of water used by the crop was 331.06, 294.11 and 267.95 mm, while under irrigated conditions the crop water use was 385.54, 346.76 and 310.48mm for D_1, D_2 and D_3 dates of sowing, 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. At all stages, the water use decreased with delay in sowing in both rainfed and irrigated conditions.

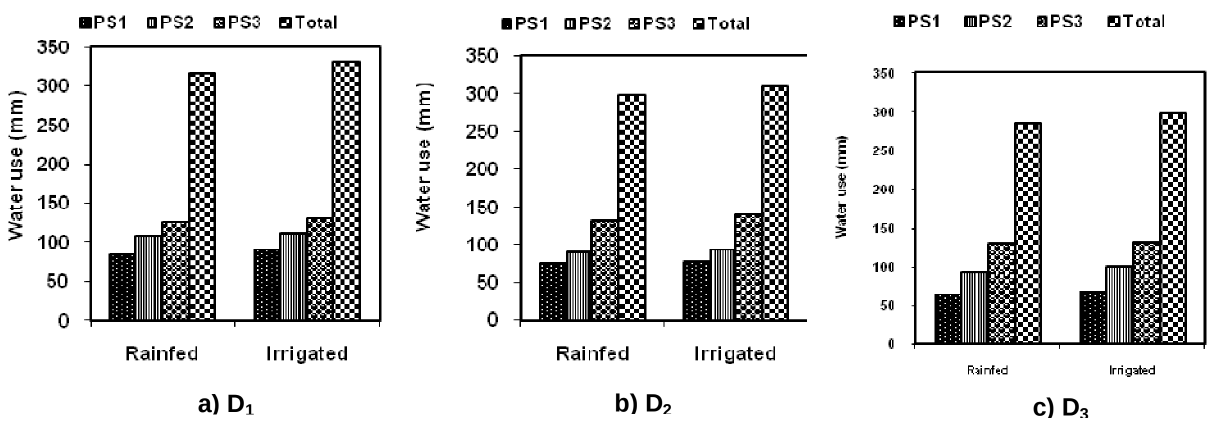

Fig. 2: Water use (mm) by mustard crop at three phenological stages under different sowing environment

Table 3: Partitioning of above ground biomass (g m^{-1}) into different components of mustard crop at PS_3 stage

Treatment	Rainfed				Irrigated			
	Leaf	Stem	Rep. Parts	Total	Leaf	Stem	Rep. Parts	Total
Varuna								
Ist Sowing (D_1)	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 (D_2)	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 (D_3)	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 Bahar								
Ist Sowing (D_1)	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 (D_2)	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 (D_3)	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

Crop water use efficiency

The crop water use efficiency, i.e., the amount of biomass produced per unit amount of water utilized (g m^{-1} mm^{-1} of water) was derived for two cultivars in three dates of sowing at different phenophases under rainfed and irrigated conditions and depicted in Fig. 3 and 4. The crop water use efficiency (CWUE) of cultivar Varuna ranged from 1.94 to 3.0, 2.01 to 3.88 and 1.80 to 2.83 g $m^{-1}mm^{-1}$ of water at D_1, D_2 and D_3 dates of sowing under rainfed condition (Fig. 3). Whereas the cultivar Pusa Bahar 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 and PS_3 stages, the same trend was followed. For whole crop period, the CWUE was 2.83, 3.95 and 3.01 and 3.37, 4.55 and 3.35 g m^{-1} mm^{-1} of water for the cultivars Varuna and Pusa Bahar, respectively in first, second and third dates of sowing, rainfed conditions. Under irrigated conditions, variety Varuna exhibited the highest CWUE during PS_3 stage for both D_1 and D_2 dates of sowing with the values being 5.99 and 4.45 g m^{-1} mm^{-1} of water, whereas it was highest at PS_3 stage (3.76 g m^{-1} mm^{-1} of water) in third date of sowing (Fig. 4). The cultivar Pusa Bahar exhibits nearly same values at PS_1 stage at all three dates of sowing. Whereas, it was maximum at PS_2 stages in all three dates of sowing. The total CWUE was 5.32, 4.19 and 3.05 g $m^{-1}mm^{-1}$ of water in D_1, D_2 and D_3 dates of sowing.

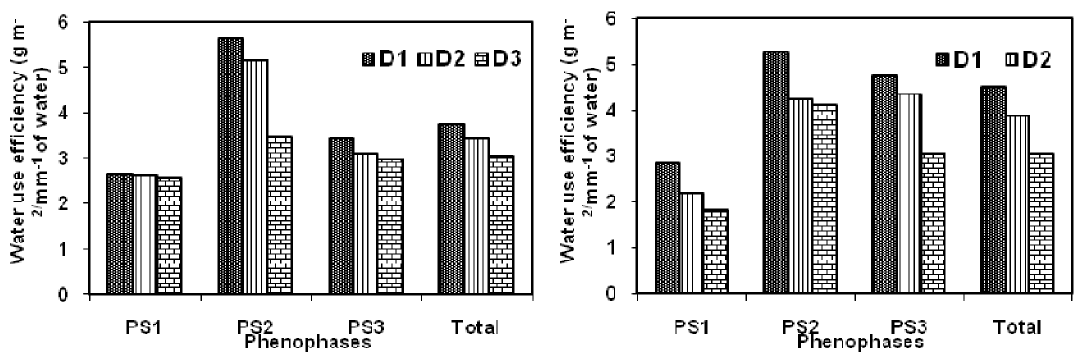

Fig.3: Crop water use efficiency (g m^{-1} mm^{-1} of water) among different dates of sowings by Varuna sown under rainfed as well as irrigated conditions

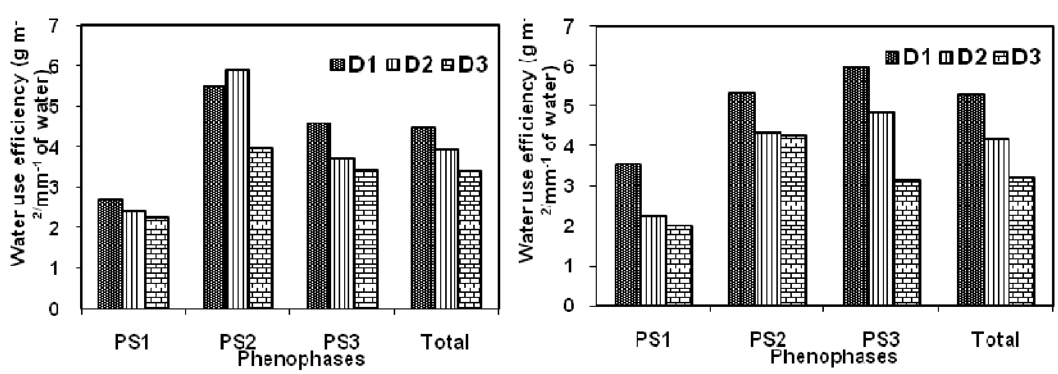

Fig.4: Crop water use efficiency (g m^{-1} mm^{-1} of water) among different dates of sowings by Pusa Bahar sown under rainfed as well as irrigated conditions

REFERENCES

Campbell, G. S. and Diaz, R. (1988) Simplified soil-water balance model to predict transpiration. In drought research priorities for the dryland tropica (Bidinger, P. R. and Johansen, C., Eds.) ICRISAT, Patancheru, A.P.

Kar, G. and Chakravarty, N. V. K. (2001) Biomass partitioning and crop water requirements of *Brassica* as influenced by sowing dates and cultivars. *Annals of Agricultural Research* 22: 42-48.

Ram Niwas, Singh, D. and Rao, V.U.M.P. (2002) Practical manual on evapotranspiration estimation. Department of Agricultural Meteorology College of Agriculture, CCS Haryana Agricultural University, Hisar - 125 004.

Singh, R., Rao, V. U. M. and Singh, D. (2002) Biomass partitioning in Brassica as affected by sowing dates. *Journal of Agrometeorology* 4 (1): 59-63.

Snyder, F. W. and Carlson, G. E. (1984) Selecting for partitioning of photosynthetic products in crops. *Advances in Agronmy* 37: 47-71.

Somayeh, R., Delkhosh, B., Rad, A.H.S. and Zandi, P. (2011) Effect of sowing dates and irrigation regimes on agronomic traits of Indian mustard in semi-arid area of Takestan. *Journal of American Science* 7(10).

Willman, M. R., Below, F. E., Limbert, R. J., Honey, A. E. and Mies, D. W. (1987) Plant traits related to productivity of maize. I. Genetic variability, environmental variation and correlation with grain yield and stalk lodging. *Crop Science* 27: 1116-1121.