Water Use efficiency and Bio mass Partitioning of Indian mustard under different environment conditions of Shivalik foot hills

Abstract

A field experiment was conducted in *Rabi* 2018–19 to look at the water requirements and above-ground biomass partitioning in mustard crops growing both rainfed and irrigated. The amount of biomass produced above ground was significantly influenced by the temperature environment and the crop's efficiency in using water during the growing season. The total buildup of above-ground biomass under irrigation was demonstrated to be higher than under rainfed conditions. In both irrigated and rainfed settings, the crop's total above ground biomass was found higher on October 07 than it was on October 21 and November 6. The impact of additional meteorological factors (such as maximum and minimum temperatures) was noted to have increased the Reference crop evapotranspiration (RCET) during the PS1 and PS3 phases relative to the PS2 stage. When the mustard crop was sown in early, normal, or late conditions, the total amount of water needed was 331.06 mm, 324.90 mm, and 303.65 mm, respectively. In comparison to the cultivar Pusa Mustard 26 (NPJ113), which was sown under rainfed and irrigation circumstances, the cultivar Pusa Mustard 27 (EJ17) had a greater crop water use efficiency (CWUE).

Keywords: Dates of sowing, crop water usage efficiency, water use, biomass partitioning, irrigation, and rainfall.

Introduction

Research on biomass synthesis and its partitioning is essential to crop management since one of the main factors affecting grain production during anthesis is the partitioning of photosynthates towards grain filling. A higher proportion of a crop's biomass must be allocated to the harvested organs in order for it to yield. Differentiating across cultivars may be restricted by very various procedures because of differences in their edaphic and the environmental conditions (Willman et al., 1987). Environmental factors and genetics regulate photosynthetic synthesis, translocation partitioning, and storage of photosynthates in plants (Snyder and Carlson, 1984). The amount of maximal biomass accumulation was much lower in late-planted crops. This could be partially attributed to the variations in water use efficiency and temperature requirements resulting from varied planting dates (Singh et al., 2002). Due to the lack of irrigation water in our nation, there is a greater need to pay attention to the efficient use of water in agricultural production [7-10]. By reducing surface runoff and increasing the amount of water retained in the soil and water table for later use, the effective water management strategy can conserve water. Water loss may be decreased by fallowing and mulching to decrease evaporative losses. Thus, the goal of the current study is to examine how the dates and cultivars of mustard crops affect the crop's biomass output, partitioning, and water usage.

Methodology

The current study was conducted during the Rabi season of 2018–19 on mustard cultivars under rainfed and irrigated circumstances at the KVK research farm in Reasi, SKUAST–Jammu. The accessible contents of phosphate, potash, and nitrogen in the experimental soil were 214, 13.8, and 129.8 kg/ha, respectively. The research farm's soil has a sandy loam texture. In order to generate distinct environments for crop growth, the treatments included three planting dates: October 07 (D1), October 21 (D2), and November 06 (D3). They also included two cultivars: Pusa Mustard 26 (V1) and Pusa Mustard 27 (V2), each with four replications, and rainfed and irrigated conditions. There were 48 possible treatment combinations when the experiment was set up in a split-split plot design. The plot was maintained at 4 m x 3 m. For the crop that was rainfed, just presowing irrigation was used. When the crop was watered, water was given at the stages of pod production, blooming, and the fifth leaf. The remainder of the package and recommended practices were adhered to. Three phenophases—PS1: emergence to flower bud initiation, PS2: flower bud initiation to siliqua development, and PS3: siliqua formation to maturity—were observed for biomass. From each plot, five plants were chosen at random and divided into sections for the leaves, stem, and siliquae. Samples were weighted after being oven dried for 48 hours at 700C. The buildup of biomass in various plant sections was then expressed in grams per square meter (g/m^2).

The Campbell and Diaz (1988) model was used to calculate potential evapotranspiration (PET). Using the formula developed by Kar and Chakravarty (2001), the Reference crop evapotranspiration (RCET) for the various sowing dates in both rainfed and irrigated conditions was determined. The Agrometeorological observatory of SKUAST-J, main campus Chatha, provided the meteorological data needed for these computations. It is situated 50 meters away from the experimental site. The following formula was used to calculate the crop's water consumption at different stages:

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

where Kc is the crop coefficient and RCET is the reference crop evapotranspiration (Ram Niwas et al. 2002).

The following formula was used to calculate the crop water use efficiency (CWUE) for biomass production in mustard cultivars under both rainfed and irrigated settings at different phases of crop growth (Kar and Chakravarty, 2001):

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

RESULTS AND DISCUSSIONS

Above ground biomass and partitioning

Partitioning, the division of assimilates (photosynthates) among various plant sections, influences the plant's survival and output. Tables 1, 2, and 3 show the biomass partitioning at different phenophases in the Pusa Mustard 27 and Pusa Mustard 26 cultivars according to planting environments under rainfed and irrigated conditions. When the crop was cultivated under irrigation rather than rainfed, a greater accumulation of total above-ground biomass was observed. When compared to other plant parts, the biomass partitioning of both cultivars during the emergence to flower bud initiation (PS1) stage was more in the leaves in all treatments; however, at the PS2 stage, it was more in the stem compared to the leaves and reproductive parts because the plant was absorbing more radiation and using more water than it was during PS1 (Table 1 & 2). Compared to PS1 and PS2 phases, siliqua development to physiological maturity showed a greater buildup of total biomass. The mean total biomass production for D1, D2, and D3 in cultivar Pusa Mustard 26 at PS1 stage was 109.99, 93.55 & 78.25 and 93.08, 81.44 & 75.92 g/m2, respectively, under irrigated and rainfed conditions (Table 1). The data clearly shows that under both rainfed and irrigated settings, the accumulation of dry matter and its distribution across various plant portions decreased with sowing delay. The amount of mean biomass buildup in the normal and late-planted crops compared to the early-planted crop was reduced by approximately 12 and 18 percent in rainfed conditions, and by 15 and 29 percent in irrigated conditions. In both cultivars, biomass allocation in leaves peaked during the emergence to bud initiation (PS1) stage and was thereafter followed by the stem under both rainfed and irrigated circumstances during the whole sowing period. The stem had the largest biomass from bud initiation to siliqua formation, followed by leaves and reproductive components in that order. The crop was sown on October 7th, yielding the highest biomass production when compared to October 22nd and November 6th, under both rainfed and irrigated conditions. The cultivar Pusa Mustard 27 showed mean values of 1028.50, 861.15 & 683.66 and 951.77, 828.35 & 614.89 g/m2 under these conditions. Peak biomass production reductions for the cultivar Pusa Mustard 27 were 16.3 and 33.5 percent in irrigated conditions and 13 and 35.4 percent in rainfed conditions in the second and third quarters of the study period. In the Pusa Mustard 26 variety grown under irrigation, the three sowings' total mean biomass production varied from 639.19 to 870.08 g/m2, with the D3 sowing accumulating the least amount of biomass. In D2 and D3, compared to D1, the decrease in biomass output was 8.5 and 26.5 percent in irrigated areas and 10 and 30.6 percent in rainfed areas. The percentage of biomass devoted to leaves peaked at PSI (57%) and thereafter decreased as a result of a greater buildup of dry matter in the stem and siliqua. Due to their poor development in terms of both absolute dry weight and percent allocations, the siliquae weight suffered the most from the delay in planting, which decreased the total dry matter output (Singh et al 2002). In both rainfed and irrigated circumstances, the delayed sowing decreased the biomass accumulation in various plant sections at all stages among different treatments. This suggests that greater daytime temperatures during the ripening phase and lower nighttime temperatures during the vegetative phase are not beneficial for mustard grain production.

Reference crop evapotranspiration

Using the Campbell and Diaz model (1988), potential evapotranspiration (PET) during various typical meteorological weeks was calculated. According to Kar and Chakravarty (2001), the PET is equal to the evapotranspiration of a reference crop. The Reference Crop Evapotranspiration (RCET) was calculated for three dates of sowing, rainfed and irrigated, at various standard meteorological weeks. After that, the data were combined for three phenological phases, as shown in Figure 1. The reference crop's evapotranspiration under rainfed conditions varied from 0.30 to 5.66, 0.30 to 6.02, and 0.36 to 7.05 mm/day in the D1, D2, and D3 dates of sowing, respectively, according to the results. In the crop that was sown under irrigation, the total RCET values were 530.97, 495.21, and 465.37 mm at D1, D2, and D3, respectively. In the crop that was rainfed, the RCET values were 504.37, 475.30, and 447.0 mm at D1, D2, and D3, respectively. When the reference crop was rainfed, its evapotranspiration was found to be lower than when it was irrigated. Because PS1 and PS3 stages take longer to complete than PS2 stages, it was seen more frequently at these stages than at PS2. Early (D1) sowing of the crop resulted in increased daily reference crop evapotranspiration (0.7 to 1.5 mm/day) compared to normal (D2) and late sowing (D3) throughout the bud initiation to siliqua development stage (PS1).

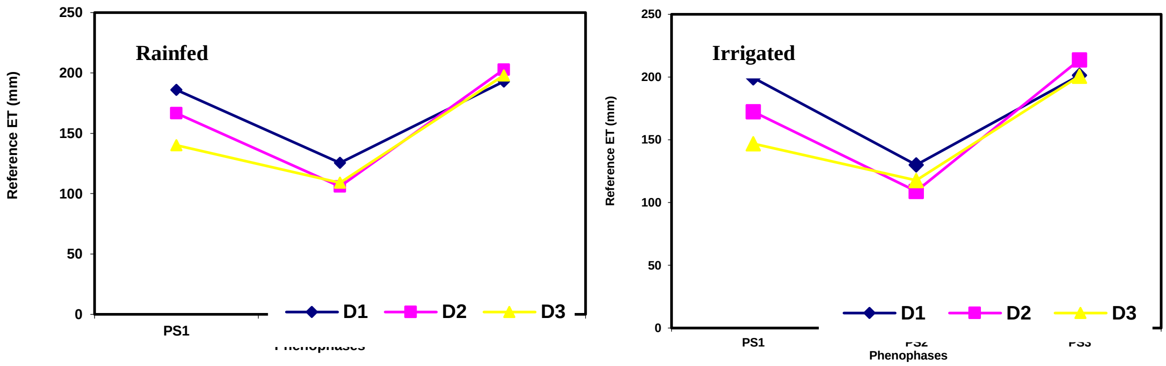


Figure 1. Reference crop evapotranspiration during various phases in a mustard crop grown in both rainfed and irrigated environments.

The RCET values at PS1 stage were 199.57, 172.40 & 146.89mm in D1, D2 and D3, respectively under irrigated conditions, while in rainfed conditions; the RCET values were 186.0, 166.60 & 140.0mm at D1, D2 and D3, respectively.

Crop water use

Figureure 2 shows the crop water use at various phenological phases sown in various sowing environments under irrigated and rainfed conditions. The overall amount of crop water used was higher when it was irrigated than when it was rainfed on all dates of sowing at various phenological stages, according to the results. The crop consumed 315.75, 296.81, and 284.35 mm of water in total when it was rainfed; under irrigation, the crop used 331.22, 309.21, and 296.66 mm of water during D1, D2, and D3, respectively. In all sowing dates under both rainfed and irrigated settings, the PS3 stage of crop growth utilized the most water, followed by the PS2 and PS1 stages. The water use decreased with delay in sowing in both rainfed and irrigated conditions.

D_1 **D_2** **D_3**

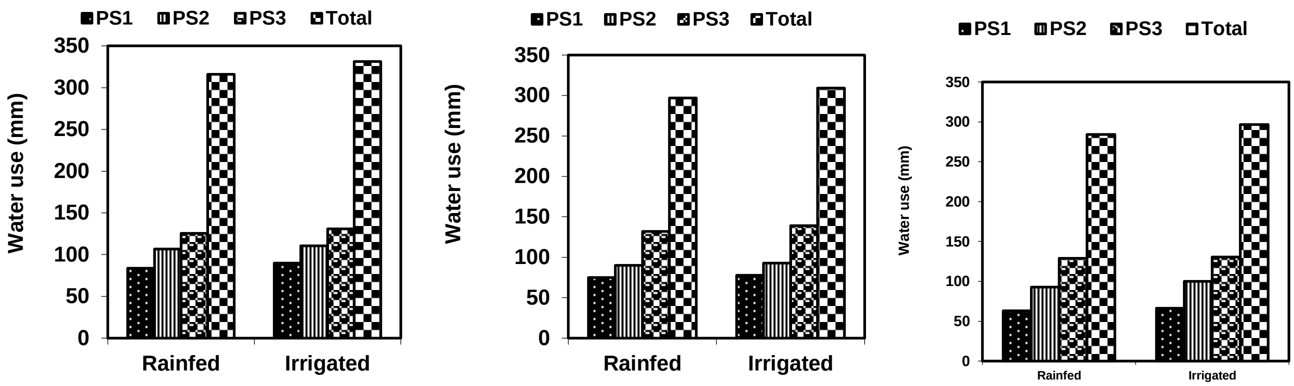


Figure 2. Water consumption (mm) of a mustard crop seeded in three distinct phenological stages and under irrigated and rainfed conditions.

Crop water use efficiency

For two cultivars in three dates of sowing at different phenophases under rainfed and irrigated conditions, the crop water consumption efficiency, or the quantity of biomass formed per unit amount of water utilized (g/m2/mm of water), was computed (Figure 3 & 4). At the D1, D2, and D3 dates of sowing, the cultivar Pusa Mustard 26 displayed a range of crop water use efficiency (CWUE) under rainfed conditions: 2.66 to 5.64, 2.62 to 5.15, and 2.57 to 3.47 g/m2/mm of water (Figure 3). However, when grown in rainfed conditions, the cultivar Pusa Mustard 27 exhibits somewhat higher amounts of CWUE at the same stages. In contrast, the water content of the cultivars Pusa Mustard 26 and Pusa Mustard 27 was 4.50, 3.87, 3.06, and 5.32, 4.18, and 3.21 g/m2/mm in early, normal, and late dates of sowing under irrigated conditions, respectively. With the exception of cultivar Pusa Mustard 27, which shows a maximum value of CWUE at PS3 stage in the first and second dates of sowing under irrigated conditions, both varieties showed the highest CWUE during PS2 stage for all dates of sowing under irrigated and rainfed settings (Figure 4). For both cultivars, the CWUE values were often higher under irrigation than under rainfed circumstances (Figure. 3 & 4).

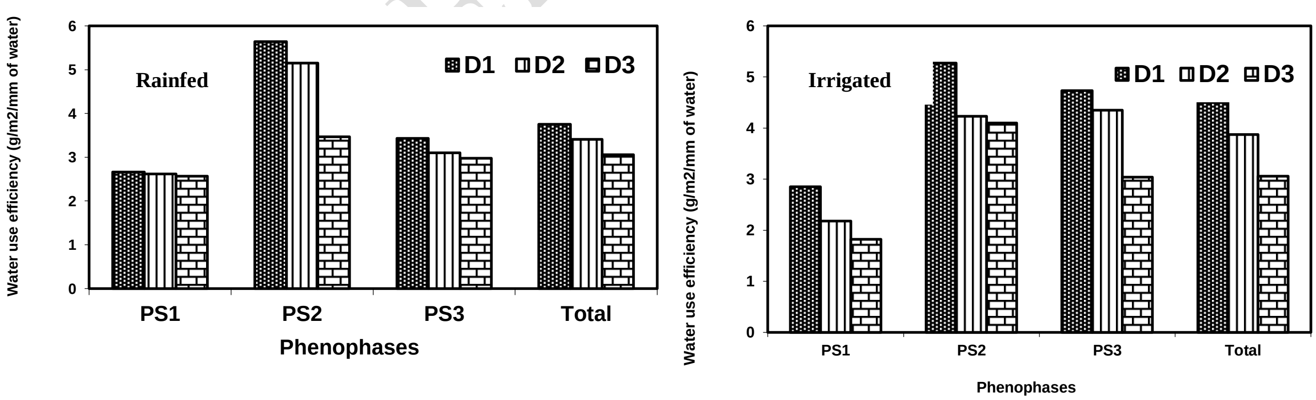
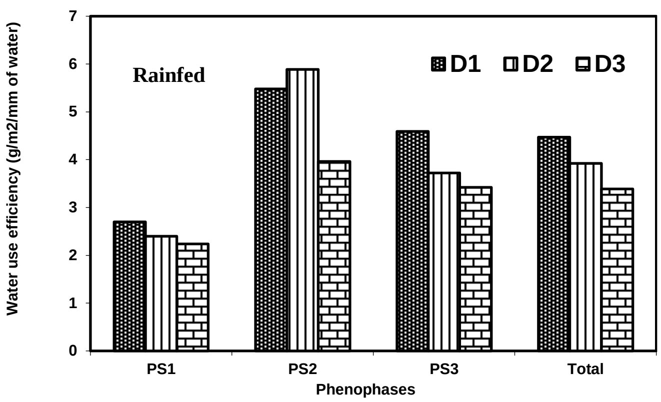


Figure. 3. Crop water use efficiency (g/m2/mm) by Pusa Mustard 26 sown under both irrigated and rainfed circumstances at different dates of sowing.



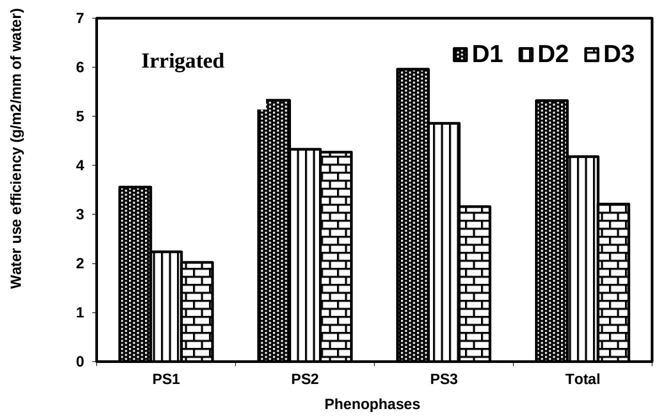


Figure. 4. Crop water consumption efficiency (g/m2/mm of water) by Pusa Mustard 27 when seeded on various dates and in both rainfed and irrigated environments.

Conclusion

The study examined how the dates and cultivars of mustard crops affect the crop's biomass output, partitioning, and water usage.In comparison to the cultivar Pusa Mustard 26 (NPJ113), which was sown under rainfed and irrigation circumstances, the cultivar Pusa Mustard 27 (EJ17) had a greater crop water use efficiency (CWUE).

Disclaimer (Artificial intelligence)

The author(s) declare that during the drafting or editing of manuscripts, NO generative AI tools, such as text-to-image generators and large language models (ChatGPT, COPILOT, etc.), were employed.

References:

1. 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.
2. Kar, G. and Chakravarty, N. V. K. 2001. Biomass partitioning and crop water requirements of *Brassica* as influenced by sowing dates and cultivars. *Ann. Agric. Res.* 22(1): 42-48.
3. Niwas, R., Singh, D. and Rao, V. U. M. 2002. Practical manual on evapotranspiration estimation. Department of Agricultural Meteorology College of Agriculture, CCS Haryana Agricultural University, Hisar-125004.
4. Snyder, F. W. and Carlson, G. E. 1984. Selecting for partitioning of photosynthetic products in crops. *Adv. Agron.* 37: 47-71.
5. 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 Sci.* 27: 1116-1121.

6. Singh, R., Rao, V. U. M. and Singh, D. 2002. Biomass partitioning in Brassica as affected by sowing dates. *J. Agromet.* 4 (1): 59-63.
7. Adak T, Kumar G, Chakravarty NV, Katiyar RK, Deshmukh PS, Joshi HC. Biomass and biomass water use efficiency in oilseed crop (Brassica juncea L.) under semi-arid microenvironments. biomass and bioenergy. 2013 Apr 1;51:154-62.
8. Rathore SS, Shekhawat K, Rajanna GA. Land configurations in surface drip irrigation for enhancing productivity, profitability and water-use efficiency of Indian mustard (Brassica juncea) under semi-arid conditions. Indian Journal of Agricultural Sciences. 2020 Aug 1;90(8):1538-43.
9. Riar A, Gill G, McDonald G. Different post-sowing nitrogen management approaches required to improve nitrogen and water use efficiency of canola and mustard. Frontiers in plant science. 2020 Jul 21;11:1111.
10. Bhukhar OS, Shivran AC, Kumawat P, Yadav LR, Dhaker DL. Water use efficiency and economics of Indian mustard (Brassica juncea L.) influenced by drip irrigation and micronutrient application methods. Indian Journal of Ecology. 2022;49(5):1691-5.

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 Figureures in parenthesis show the percentage value

Table2. Partitioning of above ground biomass (g/m²) 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 Figureures 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 Figureures in parenthesis show the percentage value