Content list available at http://epubs.icar.org.in, www.kiran.nic.in; ISSN: 0970-6429

Indian Journal of Hill Farming

December 2022, Volume 35, Issue 2, Page 184-191

Maize cultivars performance and estimation of effective rainfall during rainy season under mid hills of Meghalaya

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ARTICLE INFO

Article history:
Received: 01 December, 2022
Revision: 10 December, 2022
Accepted: 19 December, 2022

Key words: *Effective rainfall, Maize varieties, North Eastern India, Rain-fed agriculture, Rainfall efficiency, Water use efficiency.*

DOI: 10.56678/iahf-2022.35.02.27

ABSTRACT

North eastern states of India used to receive a good amount of rainfall during monsoonic precipitation and due to non-adherence of water harvesting most of the rain goes as waste to the drainage network. Hence, it is very much essential to ascertain the amount of effective rainfall used by the rainy season crops. To evaluate the efficacy of rainfall under upland situation, maize was used as a test crop. Mostly grown during rainy season, maize can perform better in winter season with assured irrigation and using resource conservation techniques. Field experiment consisted of growing three duration of maize during 2021 rainy season. Nine maize varietal treatments were used under a randomized experimental design. Out of nine varieties, three varieties were sweet corn, baby corn and grain maize each. (T1-Sugar 75, T2– NSC 904P, T3-RCM 1-61, T4 -NSC-Bio sweety, T5 -Hybrid baby corn-617, T6 -RCM 1-76, T7 -VL Sweet corn 1, T8 -G-5414 and T9 -RCM 1-75). The field experiment was replicated thrice. Among all the varieties, T1 performed well in all the treatments with highest dry matter accumulation (96.03 g plant^{-1}), crop growth rate (24.85 g m^{-2} day^{-1}), no. of seeds per cob (688.45), cob weight (132.6 g), grain yield (7.92 t ha^{-1}), cob yield (11.29 t ha^{-1}) and biological yield (21.7 t ha^{-1}). Highest rainfall use efficiency (RUE) (63.99%) and Water use efficiency (WUE) (21.07kg ha^{-1} mm^{-1}) were reported for baby corn variety (NSC 904P) as compared to sweet corn and grain maize varieties.

1. Introduction

Globally, Maize (*Zea mays* L.) is one of the most important crops (Panda *et al.,* 2004). It is used as a applicable food and animal feed worldwide which occupies a major place in the world trade and economy as an industrial grain crop (White and Johnson, 2003). Maize, a crop of global economic significance, together with rice and wheat, yields approximately 30% of the food calories to more than 4.5 billion people in 94 developing countries and maize demand is expected to double by 2050 in these countries (Shiferaw *et al.*, 2011). In India, maize is considered as the third most important food crop among the cereals and come up with nearly 9% of the national food basket (Anonymous-1, 2021). Maize is a versatile crop having greater adaptability under various types of agro-climatic conditions and has the highest genetic yield potential among all the cereals (Yadav *et al.*, 2015). Because of maize's high genetic yield potential, it is globally well known as "Queen of cereals". In India, its area is approximately 6 Mha since early 1970's, but production is below the potential (Jakhar *et al.*, 2017) because productivity remains highly unstable with annual twists essentially fashioned by the behaviour of rainfall. During its entire growing period, the amount of water required for maize crop ranges between 500-800 mm (FAO, 2013). It is the only cereal crop which can be grown in different seasons and ecologies. Firstly, Maize is used for feed (60%) followed by human food (24%), industrial products (14%), seed (1%) and beverages (1%). Thus, maize has attained a eminent position as an industrial crop because 75% of the maize that is produced is used in feed and starch industries. In India, maize is principally cultivated as rain-fed crop.

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Zea is the genus which comprises of four species, among which *Zea mays* L. is economically significant. Maize is a monoecious plant, and it has two inflorescences (tassel and silk). This crop demands less water than other similar cereals. As it is a day neutral and 'C_4' plant, it provides higher yield per hectare in a shorter time and can be grown in any season. Presently, approximately 1147.7 Mt of maize is being assembled by over 170 countries from an area of 193.7 Mha with an average amount of productivity of 5.75 t ha^{-1} (FAOSTAT, 2020). Maize contributes more than 2% to the total output value from all agricultural crops. During 2018-19, the acreage, production and productivity of this crop in India are 9.47 Mha, 27.8 Mt and 2.96 t ha^{-1}, respectively (Anonymous-1, 2021). In Meghalaya, nearly 41,624 tons of maize is being generated from an area of 18,152 ha with mean productivity of 2.3 t ha^{-1} (Anonymous-2, 2013). Maize can be produced successfully in different types of soils which ranges from loamy sandy to clay loamy. However, soils with adequate organic matter, having greater water holding capacity with neutral pH are considered fine for higher productivity.

As it is a moisture sensitive crop excess soil water and salinity stresses affect the production, hence maize grown fields should have provision for proper drainage. Increased population led to the rise of water demand that has produced the requirement in increasing food production through the rise of irrigation and industrial production to meet the human needs. Hess (2005) defined crop water requirements as the total water that is required for evapotranspiration, from planting to the harvest for a given crop in a specific climate regime, when required soil moisture is maintained by rainfall and/or irrigation, so that, it does not limit plant growth and crop yield.

Rainfed agriculture inhabits 67% of net sown area, contributing 44% of food grains supporting 40% of the population (Venkateswarlu, 2011). Rain-fed agriculture is experienced in 80% of the world's area under agriculture and produces 62% of the world's staple food (FAOSTAT, 2005). Most of the water received through rainfall cannot be utilized completely by the plant and major portion of rainfall is lost through runoff, deep percolation, evapotranspiration *etc*. North Eastern states of India (NEI) receive a good amount of rainfall which is more than the national average. So, rainfall efficiency is very crucial and needs to be estimated for proper regional based irrigation planning and field water management. Even though maize makes well organized use of water, it is contemplated as a crop which is highly susceptible to moisture stress than other crops due to its abnormal floral structure with separate male and female floral organs and the synchronous development of florets on a single ear borne on every stem (Huang *et al.,* 2006). Maize has varied responses to presence of less water based on the developmental stages. Rainfall use efficiency (RUE) is an indication of effective use of rainfall and water use efficiency varies for distinct duration maize varieties grown. Under high rainfall region of NEI, the WUE of the *kharif* season maize and the efficiency of rainfall needs to be estimated for proper rainwater management under upland situation. Keeping the above considerations an agronomic field trail has been carried out by taking baby corn, sweet corn and grain maize varieties as short, medium and long duration varieties, respectively to assess RUE and WUE of different duration maize cultivars and to study the growth and yield attributes of maize cultivars.

2. Materials and Methods

The following field experiment was managed under mid hills of Meghalaya during the year 2021*kharif* season, at the experimental area of College of Postgraduate Studies in Agricultural Sciences, Umiam, Ri-Bhoi district, Meghalaya. This experimental site is located at 91^o 18' to 92^o 18' East longitude and 25^o 40' to 26^o 20' North latitude and at an altitude of 950 m above the mean sea level (MSL). A schematic layout of the experiment site is shown in Fig. 1. The climate of Ri-Bhoi district is classified as subtropical humid type with high rainfall and cold winters. The Monsoon rainfall is normally sets in at the first fortnight of June and extends up to end of September. Withdrawal of monsoon takes place in October first week with a deceasing rainfall trend from September onwards. The experimental site experiences an average annual rainfall of 2617.10 mm with some pre monsoon showers during March to May (Ray *et al.,* 2012). The experimental site also experiences high relative humidity and low sunshine hours when compared to various parts of the country. Standard weekly weather data of rainfall (mm); number of rainy day (day); maximum and minimum temperature (^{o}C); relative humidity (%); during the period of crop growing period was recorded from nearby meteorological observatory station. The weekly rainfall (mm), average maximum and minimum temperature (^{o}C) and relative humidity (%) is shown in the following Fig. 2.

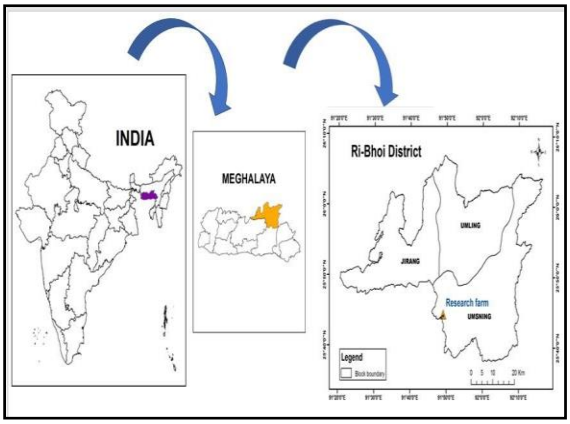

Figure 1. Location of experimental site

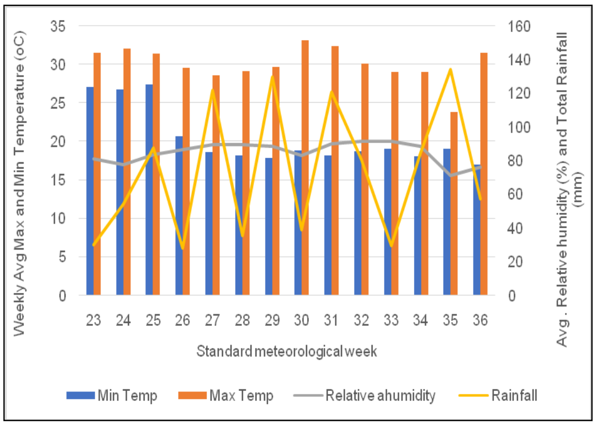

Figure 2. Weekly recorded meteorological data during the experimental period

Total rainfall received through entire crop growth period was 995 mm, of which the highest weekly rainfall of 134.4 mm was obtained during 35^{th} standard meteorological week (SMW). Mean weekly maximum temperature was recorded highest during 30^{th} SMW (33.14^{0}C) and the lowest was recorded in 35^{th} SMW (23.86^{0}C). Mean weekly maximum temperature was recorded highest in 25^{th} SMW (27.43^{0}C) and the lowest was recorded in 36^{th} SMW (17^{0}C). The mean recorded weekly relative humidity varied from 71.27 to 91.69%.

The experiment was laid under randomized block design in which nine (09) maize varieties (three varieties of baby corn, three varieties of sweet corn and three varieties of grain maize) were used and is replicated thrice. The seed rate followed was 20 kg ha^{-1}, with spacing of 60 × 20 cm^2 and recommended doses of fertilizer application as (120: 60: 40 kg ha^{-1}) of N: P_2O_5: K_2O. During sowing time, full doses of P, K and 50% of N dose was applied as basal and the rest 50% of N fertilizer was applied at tasseling stage through basal. The treatment details are T1 – Sugar 75; T2 – NSC-904P; T3 – RCM-1-61; T4 – NSC-Bio sweety; T5 – Hybrid Baby corn-617; T6 – RCM-1-76; T7 – VL Sweet corn-1; T8 – G-5414 and T9 – RCM-1-75. Standard agronomical and protection measures were adopted during the crop growth period and accordingly different crop growth and yield attributes were recorded.

To estimate effective rainfall during the rainy season, *in-situ* soil moisture monitoring was taken up to 60 cm of soil depth. Gravimetric readings were taken at 2 days interval. Soil samples of each experimental plot were taken with a soil auger at depth (0-15 cm) and was put in aluminum box and weight was taken with the use of digital balance. The soil samples were put in oven at 105^{0}C for 24 hr and weighed again until constant weight was obtained. Soil moisture content was calculated by using the formula (Jalota *et al.,* 1998) presented in Eq. 1.

Soil moisture content (%)
= [Weight of soil moisture evaporated (g) / Dry soil weight (g)] × 100 …. (1)

Similarly effective depth of the rainfall was quantified by using field capacity (FC) and moisture content of soil prior to rainfall (MC) in %, bulk density and effective root zone depth of the crop as given in Eq. 2.

Effective depth of rainfall
= [(FC – MC)/100] × Bulk density × Effective root zone depth of crop …. (2)

Effective rainfall was quantified by calculating the depth of the rainfall at four depths of soil (0-15 cm, 15 - 30 cm, 30 - 45 cm and 45 - 60 cm). Thus, summation of obtained depth of rainfall at all the four depths gives effective rainfall.

Rainfall use efficiency of crop was defined as the ratio of effective rainfall to the rainfall received during entire crop growth period as presented in Eq. 3.

Rainfall use efficiency
= (Effective rainfall / Rainfall received during the entire crop growth period) × 100 …. (3)

Moisture content prior to rainfall (MC) was calculated by collecting the soil sample at four depths after every two non-rainy days. These samples were kept in the oven at 105^{o}C for one day. And the moisture content was calculated by using Eq. 1. The value taken for effective root zone depth of maize was 60 cm. The PWP and bulk density values taken for four different depths are presented in Table 1.

Table 1. Field capacity (FC), permanent wilting point (PWP) and bulk density of soil at different soil depths

Soil depth (cm)	FC (%)	PWP (%)	Bulk density (g cc^{-1})
0-15	22.4	8.66	1.34
15-30	22.8	10.02	1.40
30-45	22.6	10.60	1.42
45-60	22.6	10.87	1.44

Total rainfall received at the time of entire crop growth period for various maize varieties was estimated by collecting the daily rainfall data till the crop was harvested. Water use efficiency of the any crop was calculated by using the ratio of the crop yield obtained to the total water required for the crop growth as shown in Eq. 4. Effective rainfall obtained for different maize cultivars was taken as the amount of water required for the entire growth of crop.

Water Use Efficiency (WUE)

= [Crop yield / Total amount of effective rainfall] × 100 …. (4)

3. Results and Discussions

Effect of varietal treatments on growth attributes of maize cultivars

Field observation on plant growth attributes parameters, *viz.*, plant height, number of leaves per plant, dry matter per plant, crop growth ratio (CGR), relative growth ratio (RGR) and days to maturity has been recorded and presented in Table 2. Significant influence of rainfall was observed on the growth parameters of maize cultivars such as plant height, dry matter accumulation per plant, CGR and days to maturity.

Significant results were obtained for the plant height of all the varieties during 60 days after sowing (DAS). At 60 DAS, among all the treatments, the plant height was recorded significantly highest in T9 (254.4 cm) over T3 (205.4 cm), T6 (201.3 cm), T2 (199.9 cm), T1 (195.2 cm), T8 (189.2 cm), T4 (177.8 cm), T7 (177.5 cm) and T5 (149.4 cm). The reason for high plant height in grain maize varieties may be obtained due to genetic characteristics of the individual varieties and also rapid growth rate of the species. These results were supported by (Duivenbooden *et al.,* 2000; Chai *et al.,* 2016; Chaudhary *et al.,* 2016) in grain maize. Non-significant among all the varieties at 60 DAS. At 60 DAS, highest leaves per plant was observed in T3 (11.02) followed by T9 (11.00), T6 (10.1), T1 (9.92), T4 (9.89), T2 (9.67), T8 (9.65), T7 (9.45) and T5 (9.22). Alike results were concluded by (Yi *et al.*, 2010; Chai *et al.*, 2016; Chaudhary *et al.*, 2016) in grain maize. The reason may be be due to longer vegetative phase of grain maize varieties than baby corn and sweet corn varieties. At 60 DAS, significantly maximum dry matter accumulation was observed in T1 (96.03 g) followed by T3 (76.83 g), T5 (74.87 g), T8 (67.55 g) and T6 (63.51 g). However, treatments T4 (84.17 g), T7 (83.12 g), T2 (83.1 g), T8 (82.56 g) were at par with T1. Thus, the dry matter accumulation of sweet corn varieties was higher than baby corn and grain maize cultivars. The reason behind it may be due to ascribed to congenial abiotic factor during developmental stage of the crop. Similar effect was reported by findings of Bandyopadhyay and Mallick, 2003; Singh *et al.*, 2012; Wadile *et al.,* 2016; Padma *et al.*, 2018 in sweet corn. The maximum value of CGR was reported during 30-60 DAS. At 30-60 DAS, significantly highest CGR value was recorded in T1 (24.85) followed by T8 (21.27), T2 (21.08), T5 (19.49), T3 (19.12), T9 (17.11) and T6 (15.94). However,

Table 2. Effect of varietal treatments on growth parameters of maize cultivars

Treatments	Plant height (cm)	No. of leaves per plant (no.)	Dry matter (g $plant^{-1}$)	CGR	RGR	Days to maturity
T1	195.2	9.92	96.03	24.85	0.0396	79.67
T2	199.9	9.67	83.1	21.08	0.0377	61.67
T3	205.4	11.02	76.83	19.12	0.036	92.33
T4	177.8	9.89	84.17	21.71	0.04	81.33
T5	149.4	9.22	74.87	19.49	0.038	60.0
T6	201.3	10.1	63.51	15.94	0.034	92.0
T7	177.5	9.45	83.12	21.42	0.0397	83.33
T8	189.2	9.65	82.56	21.27	0.0393	61.33
T9	254.4	11	67.55	17.11	0.0383	93.67
SE(m)±	14.49	0.73	5.44	1.15	0.003	4.16
CD (P=0.05)	43.45	NS	16.32	3.46	NS	12.48

T4 (21.71) and T7 (21.42) were at par with T1. CGR was minimum at the beginning, which might be due to as it required 5-8 days for emergence of the plants. And this value was rapid at active vegetative stage, might be due to rapid cell division and elongation. The results showed that the crop growth rate of sweet corn varieties was higher than baby corn and grain maize varieties. These findings conformity with the findings that were done earlier by Babar and Bhaskar, 2015; Chai *et al.,* 2016; Wadile *et al.,* 2016; Duivenbooden *et al.,* 2000. During 30-60 DAS, maximum value of RGR was observed in T4 (0.04) over T7 (0.0397), T1 (0.0396), T8 (0.0393), T9 (0.0383), T5 (0.038), T2 (0.0377), T3 (0.036) and T6 (0.034). It shows that the RGR of sweet corn cultivars was maximum when compared to baby corn and grain maize varieties. This variation may be due to variation in the dry matter accumulation among different treatments. Similar results have been suggested by Bandyopadhyay and Mallick, 2003; Yi *et al.*, 2010; Kara *et al.*, 2012; Singh *et al.*, 2012; Chaudhary *et al.,* 2016; Wadile *et al.*, 2016. There is significant difference observed for days taken to maturity among all the treatments. T9 (93.67) reported significantly highest number of days for maturity, whereas, T5 (60) reported least number of days for maturity. However, numbers of days for maturity of other treatments were T3 (92.33), T6 (92), T7 (83.33), T4 (81.33), T1 (79.67), T2 (61.67) and T8 (61.33). It shows that, the days taken for maturity of grain maize varieties was higher than sweet corn and baby corn varieties, which might be due to long duration of crop growth of grain maize varieties. Alike results were found by Kara *et al.*, 2012; Chaudhary *et al.*, 2016; Goswami *et al.*, 2019.

Effect of varietal treatments on yield attributes of maize cultivars

Similarly, field observations on different yield attributes of maize cultivars were recorded. The yield attribute parameters are grain yield, cob yield; biological yield and WUE of different maize cultivars were also estimated and statistically analyzed. The analyzed data is presented in Table 3.

The data recorded on maize grain yield was found significant among all the treatments. Significantly highest amount of grain yield was observed in T1 (7.92 t ha^{-1}) followed by T2 (6.84 t ha^{-1}), T8 (6.26 t ha^{-1}), T5 (5.98 t ha^{-1}), T6 (4.90 t ha^{-1}) and T9 (4.66 t ha^{-1}). T1 was at par with T4 (7.18 t ha^{-1}) and T7 (6.93 t ha^{-1}). T3 reported the lowest grain yield, *i.e.,* 4.26 t ha^{-1}. The results reported that, the grain yield of sweet corn varieties was higher than baby corn and grain maize varieties. Alike results were reported by Kara *et al.*, 2012. Wadile *et al.*, 2016. Goswami *et al.*, 2019. Significantly highest cob yield was recorded in T1 (11.29 t ha^{-1}), which is on par with T4 (10.62 t ha^{-1}) and T7 (10.62 t ha^{-1}). The cob yield reported by T2, T8, T5, T6, T9 and T3 was 9.06 t ha^{-1}, 8.26 t ha^{-1}, 8.21 t ha^{-1}, 7.09 t ha^{-1}, 6.54 t ha^{-1} and 6.42 t ha^{-1}, respectively. T3 recorded the lowest cob yield, *i.e.,* 6.42 t ha^{-1} and significantly maximum biological yield was recorded in T1 (21.7 t ha^{-1}), which is on par with T4 (21.2 t ha^{-1}), T7 (20.65 t ha^{-1}), T9 (20.3 t ha^{-1}), T3 (20.2 t ha^{-1}) and T6 (18.4 t ha^{-1}). The biological yield observed by treatments T2 and T8 was 13.2 t ha^{-1} and 11.47 t ha^{-1}, respectively. T5 reported the lowest biological yield, *i.e.*, 11.24 t ha^{-1}. The results reported that the cob yield and biological yield of sweet corn varieties was higher than baby corn and grain maize varieties. This higher yield may be due to more dry matter accumulation and production of higher amount of biomass. Higher grain yield may be attributed to higher production efficiency. Thus, efficient assimilation and translocation of photosynthates increases the yield performance of the crop. Alike results were reported by Gregory, 2004; Babar and Bhaskar, 2015; Wadile *et al.*, 2016.

Table 3. Effect of varietal treatments on yield parameters and water use efficiency of maize cultivars

Treatments	**Grain yield ($t\ ha^{-1}$)**	**Cob yield ($t\ ha^{-1}$)**	**Biological yield ($t\ ha^{-1}$)**	**WUE ($kg\ ha^{-1}\ mm^{-1}$)**
T1	7.92	11.29	21.7	17.59
T2	6.84	9.06	14.1	21.07
T3	4.26	6.42	20.2	5.87
T4	7.18	10.62	21.2	16.79
T5	5.98	8.21	12.98	18.78
T6	4.90	7.09	18.4	7.30
T7	6.93	10.62	20.7	16.12
T8	6.26	8.26	13.18	19.66
T9	4.66	6.54	20.3	5.62
SE(m)±	0.35	0.61	1.21	0.84
CD (p=0.05)	1.06	1.82	3.62	2.51

Rainfall and Water use efficiency of maize cultivars

The variation of soil moisture content obtained prior to rainfall at four different depths of soil (0 - 15 cm, 15 - 30 cm, 30 - 45 cm and 45 - 60 cm) on different dates of crop growth period are shown in Fig. 3, 4, 5 and 6, respectively. It may be noted from the soil moisture variation graphs, that major variation takes place at the upper soil surface as compared more depth soil. These *in-situ* soil moisture variations are closely related with the findings of Dey *et al.*, 2017; Marwein *et al.*, 2017. The rainfall use efficiency was calculated as the actual amount of rainfall that was efficiently used by the crop for its growth. Table 4, presents the data recorded on rainfall use efficiency of maize cultivars. Rainfall use efficiency was calculated as the effective rainfall out of total amount of rainfall received for entire crop growth period. The results were found significant among all the treatments. Significantly highest rainfall efficiency was found in T2 (63.99%) over T7 (53.06%), T9 (52.98%), T6 (45.48%) and T3 (45.29%) but it is at par with T8 (62.77%), T5 (62.75%), T1 (59.01%) and T4 (55.52%). The water use efficiency was also found significant among all the treatments. Highest WUE was found in T2 (21.07 kg ha^{-1} mm^{-1}) over T1(17.49 kg ha^{-1} mm^{-1}), T4(16.79 kg ha^{-1} mm^{-1}), T7 (16.12 kg ha^{-1} mm^{-1}), T6 (7.30 kg ha^{-1} mm^{-1}), T3 (5.87 kg ha^{-1} mm^{-1}) and T9 (5.62 kg ha^{-1} mm^{-1}) but it is at par with T8 (19.66 kg ha^{-1} mm^{-1}) and T5 (18.78 kg ha^{-1} mm^{-1}). Thus, the results revealed that rainfall efficiency and WUE of baby corn varieties were higher compared to sweet corn and grain maize varieties. Alike findings were obtained by comparing the results of Shivakumar *et al.*, 2011, Garcia *et al.*, 2009 and Kresovic *et al.*, 2016.

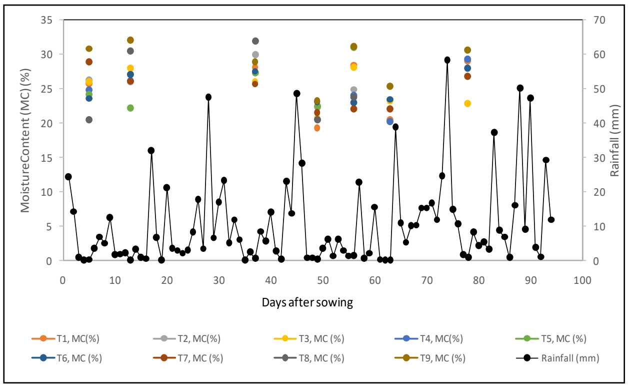

Figure 3. Variation of *in-situ* soil moisture content prior to rainfall (%) under different treatments at 0-15 cm depth of soil

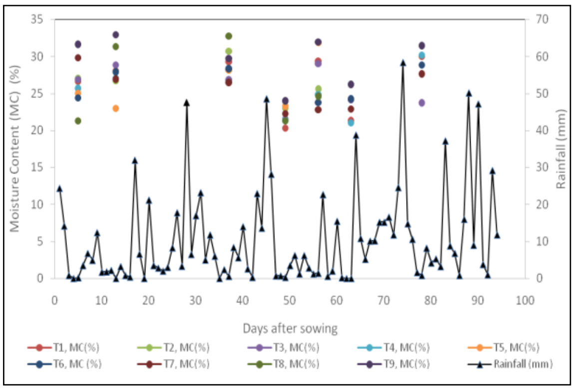

Figure 4. Variation of *in-situ* soil moisture content prior to rainfall (%) under different treatments at 15-30 cm depth of soil

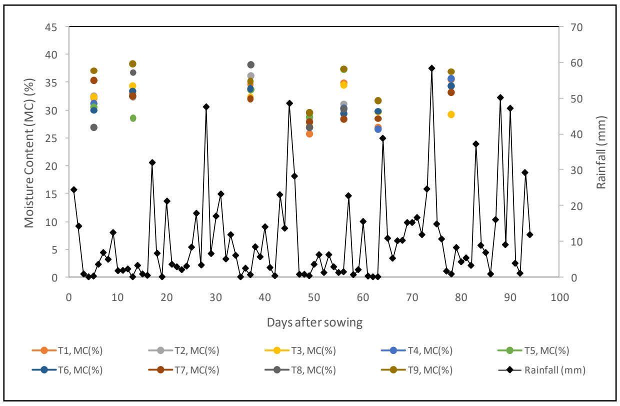

Figure 5. Variation of *in-situ* soil moisture content prior to rainfall (%) under different treatments at 30-45 cm depth of soil

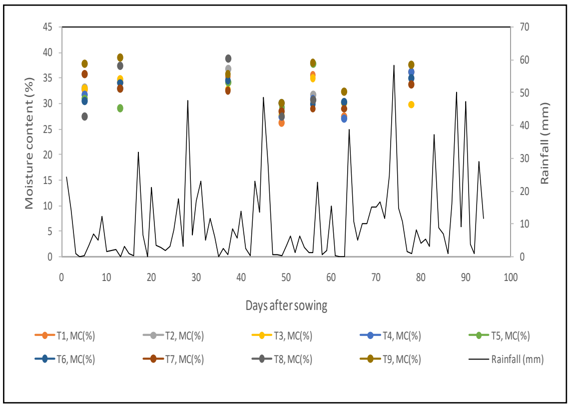

Figure 6. Variation of *in-situ* soil moisture content prior to rainfall (%) under different treatments at 45-60 cm depth of soil

Table 4. Total rainfall received, effective rainfall and rainfall efficiency obtained for different maize cultivars

Treatments	Total rainfall received (mm)	Effective rainfall (mm)	Rainfall use efficiency (%)
T1	763.3	450.35	59.01
T2	507.2	324.60	63.99

T3	954.0	436.35	45.29
T4	770.0	427.48	55.52
T5	507.4	318.40	62.75
T6	954.0	438.26	45.48
T7	810.4	430.00	53.06
T8	507.4	318.48	62.77
T9	983.2	527.06	52.98
SE(m)±	-	-	3.38
CD (p =0.05)	-	-	10.13

4. Conclusion

Field water management is feasible only when estimation of various sources of water available in the field is quantified suitably. Under high rainfall zones, suitable water harvesting strategies and design of water harvesting structures can be possible by quantifying effective rainfall. From the present investigation, it was estimated that out of total annual rainfall of more than 1800 mm, around 983 mm was received during rainy season in 2021. Accordingly, the range of rainfall use efficiency estimated was 45.29 to 63.99%. These values indicate provisions may be made for storing the extra amount of rainfall under hilly regions for harvesting using suitable harvesting techniques. Similarly the range of WUE of maize cultivars under rainfed farming system varies between 5.62 to 21.07 kg ha^{-1} mm^{-1}. The estimated values were very less; however, necessary crop planning may be made to enhance the WUE. Among different maize cultivars, Sugar-75 performed better with highest grain yield (7.92 t ha^{-1}), cob yield (11.59 t ha^{-1}) and biological yield (21.7 t ha^{-1}). Highest rainfall and water use efficiency was reported by the baby corn varieties compared to sweet corn and grain maize varieties. NSC-904P variety had shown highest RUE (63.99%) and WUE (21.07 kg ha^{-1} mm^{-1}) over other varieties. Since maize cultivar, sugar-75 performed better, farmers of the NEI should go for cultivating sugar-75 during rainy season for enhancing their profit.

5. Acknowledgement

The authors would like to extend their gratitude to All India Coordinated Research Project (AICRP) on maize staffs for providing seeds.The financial assistance acquired from CAU-Imphal at the time of the tenure of the M.Sc. programme is also acknowledged.

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