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Research Paper

Productivity and profitability of maize (*Zea mays*) cultivars under organic management condition in mid-hills of Sikkim

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ABSTRACT

A field experiment was conducted during pre-rainy (*kharif*) seasons of 2019 and 2020 at Research Farm of ICAR Research Complex for North Eastern Hill Region, Sikkim Centre, Tadong, Gangtok, Sikkim to evaluate the performance of maize (*Zea mays* L.) cultivars under organic management condition. Twelve cultivars of maize, viz. 'Seti Makkai', 'Pahenlo Makkai', 'Rato Makkai', 'Baiguni Makkai', 'Kalo Makkai', 'Satheya', 'RCM 1–1', 'RCM 1–3', 'RCM–75' and 'Vivek Sankul 31', 'Vivek Sankul 37' and 'Vivek Sankul 35' were evaluated under organic management system in randomized complete block design. The results showed that cultivar 'Seti Makkai' recorded significantly maximum plant height (305 cm) as compared to the other cultivars. The highest dry-matter accumulation (81 g/plant) was registered under 'Rato Makkai' which was significantly superior to that of remaining cultivars. The maximum leaf-area index was recorded under 'Vivek Sankul 35' (4.35) as compared to the other cultivars. The minimum days required to 50% flowering (61 days) was noticed under 'Vivek Sankul 35'. As compared to the other cultivars, the maximum cob length (16.7 cm) was recorded under 'RCM 1-1'. 'Vivek Sankul 31' registered significantly higher cob girth (13.4 cm) than the others. Number of rows/cob (12.9) was significantly higher in 'Vivek Sankul 35' than the remaining cultivars. Maximum number of grains/row was registered in 'Kalo Makkai' (36.8). The highest grain yield (3.97 t/ha) and economic benefits were recorded with 'Vivek Sankul 35' as compared to the remaining cultivars. Short- duration maize cultivar 'Vivek Sankul 35' was found most promising in terms of productivity and profitability and may be recommended for cultivation by farmers of Sikkim Himalayas and similar agro-ecoregions under organic production system.

Key words: Maize cultivars, Organic farming, Productivity, Profitability

Maize (*Zea mays* L.) is the most potential and predominant crop in rainfed region of Sikkim Himalaya as well as whole North-Eastern Hill region owing to its multiple uses as food, feed and fodder. It has fabulous genetic diversity, which allows it to thrive in tropical, subtropical and temperate climate (Babu *et al*., 2020). The agrarian economy of north-eastern region is rice (*Oryza sativa* L.)/maize-based and majority of the population uses maize as a secondary food purpose, consumed as maize rice 'Makkai ko Chamal' and also used as a local liquor (*Jhand*/*Rakshi*) (Singh *et al*., 2020). In India, Sikkim becomes a first organic state and demand of organic maize is more in national and international market. In India, maize is cultivated around 9.47 million ha area, with 28.6 million tonnes production and 2,900 kg/ha productivity (ENVIS Centre Sikkim, 2020). Among different states, Sikkim occupied about 38.5 thousand ha area with 67.96 thousand tonnes production and 1,767 kg/ha productivity which is far below the national average. Various reasons for low productivity are: cultivation of long duration local cultivars, non-availability of seeds of high-yielding varieties, low solar radiation, high incidence of insect-pests, diseases and weeds, and poor soil management (Avasthe *et al.,* 2020). Farmers of Sikkim generally grow low-yielding traditional cultivars 'Murli Makai' 'Sikkim Primitive', 'Kali Makai' (with dark purplish-black kernel type), 'Rathi Makai' (with dark red

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kernels), 'Paheli Makai' (with yellow/ orange flint kernel type), 'Seti Makai' (with white kernel type), 'Putali Makai' (with transposon-induced pericarp variegation), 'Chaptey Makai' (with white, dent type kernels), 'Gadbade Makai' (predominantly white kernels with some purple flint kernels), 'Bancharey Makai' (a high-altitude maize with yellow, flint-kernel type), 'Kukharey Makai' (with short-statured plants), 'Kuchungdari' (with orange coloured popcorn-type kernels), and 'Kuchungtakmar' (with a mix of yellow, white, purple and red kernels)] (Kapoor and Lata, 2013). Hence, it was hypothesized that introduction of high-yielding cultivars of maize may increase the productivity and profitability/unit of investment under organic farming system. Keeping these in view the present study was carried out to study the performance of maize cultivars under organic management condition in mid-hills of Sikkim.

MATERIALS AND METHODS

A field experiment was conducted during pre-rainy *(kharif)* season of 2019 and 2020 at Research Farm of ICAR Sikkim Centre (27°32' N and 88°60' E, 1,300 m above mean sea-level). The total rainfall of about 1,350 mm was received during the crop-growing period. The maximum average temperature (28.1°C) was noted in September and the minimum (8.4°C) in December. The maximum relative humidity (91.7%) was recorded in July and the minimum in April (42%). The soil of the research experiment site was clay loam having bulk density (1.28 Mg/m^3), *p*H 5.46, electrical conductivity (0.24 dS/m), high organic carbon (1.12%), low available N (347 kg/ha), medium available P (15.2 kg/ha) and high available K (360 kg/ha). Twelve cultivars of maize 'Seti Makkai', 'Pahenlo Makkai', 'Rato Makkai', 'Baiguni Makkai', 'Kalo Makkai', 'Satheya', 'RCM 1–1', 'RCM 1–3', 'RCM–75' and 'Vivek Sankul 31', 'Vivek Sankul 37' and 'Vivek Sankul 35' were evaluated in a randomized complete block design with 3 replications. The organic nutrients were supplied through FYM (containing 0.54% N and 0.26% P and 0.51% K), vermicompost (containing 1.84% N and 0.92% P and 1.49% K) and biofertilizers (multiplex naalpak). The soil *p*H was neutralized before planting by applying 2 t/ha of dolomite. The nutrient requirements was fulfilled by the application of FYM at 10 t/ha + vermicompost at 2.50 t/ha, either separately or together as a basal dose. Neem-cake was added @ 150 kg/ha to the field for effective control of soil-borne insect-pests. Maize cultivars were sown in 30 cm × 10 cm crop geometry during the first fortnight of February with seed rate of 20–25 kg/ha and harvested in the second week of June. The crop was raised with recommended package of practices. During the crop-growing period data with respect to different parameters of growth, yield attributes and yield of maize were collected. Economics of different treatments were calculated by using following formulae.

Gross returns (₹/ha)=Monetary returns of seed yield (₹/ha) + Stover yield (₹/ha)

Net returns (₹/ha)=Gross returns (₹/ha) – Total cost of cultivation (₹/ha)

$$\text{Returns per rupee invested} = \frac{\text{Gross returns (₹/ha)}}{\text{Cost of cultivation (₹/ha)}}$$

$$\text{Profitability (₹/ha/day)} = \frac{\text{Net returns (₹/ha)}}{\text{Crop period (days)}}$$

$$\text{Production efficiency (kg/ha/day)} = \frac{\text{Grain yield of maize (kg/ha)}}{\text{Crop period (days)}}$$

The data collected of different parameters were subjected to appropriate statistical analysis under randomized complete block design by following the procedure of ANOVA analysis of variance (SAS Software packages, SAS EG 4.3). Significance of difference between means was tested through 'F' test and the least significant difference (LSD) was worked out where variance ratio was found significant for treatment effect. The treatment effects were tested at 5% probability level for their significance. A principal component analysis (PCA) was carried out using the biplot method in Matlab R2019b version 9.7 to determine the impact of different cultivars on growth parameters and yield attributes of maize under organic management condition (Math Works Inc., USA).

RESULTS AND DISCUSSION

Growth, yield attributes and yield

Across the study years, different cultivars of maize had significant effect on growth, yield attributes and yield of maize (Table 1). The maize cultivar 'Seti Makkai' showed significant maximum plant height (305 cm) as compared to the other cultivars but remained at par with Rato Makkai and Baiguni Makkai. The 'Rato Makkai' gave the highest amount of dry-matter accumulation (81 g/plant) being significantly superior to the remaining cultivars. 'Vivek Sankul 35' showed the maximum leaf area index (4.35) at silking stage which was statistically at par with 'Rato Makkai' and 'Baiguni Makkai' but significantly higher than the other cultivars. 'Vivek Sankul 35' taken minimum number of days (61 days) for 50% flowering and was at par with 'Vivek Sankul 31', 'Vivek Sankul 37' and 'Satheya'. The maximum cob length (16.7 cm) was recorded from 'RCM 1-1' which was at par with 'Seti Makkai' and 'Rato Makkai' but significantly higher than the remaining cultivars. Significant the highest cob girth (13.4 cm) was noticed under 'Vivek Sankul 31'. Higher number of rows/cob

Table 1. Growth, yield-attributing characters and yield of different varieties of maize under organic production system (mean data of 2 years)

Cultivars	Plant height at harvesting (cm)	Dry-matter accumulation at tasseling (g/plant)	LAI at silking stage	Days to 50% tasseling	Cob length (cm)	Cob girth (cm)	Rows/ cob	Grains/ row	Grain yield (t/ha)
'Seti Makkai'	305	72.4	3.07	72.7	16.0	11.4	11.4	31.0	3.83
'Pahenlo Makkai'	237	50.5	3.25	68.0	14.9	11.6	11.3	33.7	3.42
'Rato Makkai'	277	81.0	4.25	71.0	16.1	11.3	11.0	36.6	3.31
'Baiguni Makkai'	296	43.2	4.34	71.0	15.4	11.2	11.5	30.4	3.37
'Kalo Makkai'	258	46.8	3.48	67.3	14.0	10.4	8.67	36.8	3.21
'Satheya'	264	45.6	3.51	63.0	13.4	10.6	9.07	28.0	3.19
'RCM 1-1'	219	46.5	3.66	65.8	16.7	10.4	10.6	29.4	3.60
'RCM 1-3'	225	45.2	3.47	68.0	15.2	11.6	11.3	27.1	3.70
'RCM 75'	231	49.7	3.95	67.7	15.3	11.7	11.6	32.2	3.45
'Vivek Sankul 31'	149	22.8	3.33	62.8	13.4	13.4	11.6	34.5	3.91
'Vivek Sankul 37'	157	24.2	3.74	62.0	11.3	12.0	12.4	30.4	3.76
'Vivek Sankul 35'	138	31.4	4.35	61.0	12.2	13.2	12.9	30.7	3.97
SEm±	9.71	1.11	0.04	0.93	0.42	0.56	0.68	1.05	0.14
CD (P=0.05)	27.8	3.09	0.13	2.66	1.20	1.60	1.96	3.02	0.40

*LAI, leaf-area index

(12.9) was recorded with 'Vivek Sankul 35' which was at par with 'Vivek Sankul 37' and significantly higher than the remaining cultivars. Significant maximum number of grains/row was noted with 'Kalo Makkai' (36.8) as compared to the others but remained at par with 'Rato Makkai'. Cultivar 'Vivek Sankul 35' gave the highest grain yield (3.97 t/ha), being at par with Vivek 'Sankul 31', 'Vivek Sankul 37', 'RCM 1-3' and 'Seti Makkai'. Many similar studies have indicated that varieties have significant impact on growth and yield components (Kapoor and Lata, 2013; Kumar *et al*., 2018).

Correlation study

Pearson's correlation analysis (Table 2) indicated that, plant height showed highly significant correlation with days to 50% tasseling and days to 75% maturity at 1% level of probability, while it showed negative correlation with cob diameter and number of rows/cob. Days to 50% tasseling had significant correlation with plant height, days to 75% maturity and cob length at 1% level of probability, whereas negative correlation with cob diameter and number of rows/cob. Days to 75% maturity had highly significant correlation with plant height, days to 50% tasseling and cob length at 1% level of probability but showed negative correlation with cob diameter and number of rows/cob. The cob diameter and the number of rows/cob exhibited negative connection with cob length, while cob length showed a highly significant correlation with days. Cob diameter revealed highly significant correlation with number of rows/cob at 1% level of probability but showed negative correlation with others except number of grains/row. At 1% level of probability, the number of rows/cob exhibited a highly significant correlation with the cob diameter, but a negative with the others.

Principal component analysis of growth and yield attributes

The results shown in principal component analysis (PCA) exercised on the growth and yield attributes extracted 2 dominant principal components PC_1 and PC_2 ac-

Table 2. Correlation matrix

	Plant height (cm)	Days to 50% tasseling	Days to maturity (75%)	Cob length (cm)	Cob diameter (cm)	Number of rows/cob	Number of grains/row
Plant height (cm)	1.000	0.864	0.834	0.693	-0.729	-0.508	0.071
Days to 50% tasseling	0.864	1.000	0.894	0.803	-0.473	-0.144	0.193
Days to maturity (75%)	0.834	0.894	1.000	0.704	-0.501	-0.282	0.211
Cob length (cm)	0.693	0.803	0.704	1.000	-0.514	-0.232	0.061
Cob diameter (cm)	-0.729	-0.473	-0.501	-0.514	1.000	0.761	0.076
Number of rows/cob	-0.508	-0.144	-0.282	-0.232	0.761	1.000	-0.167
Number of grains/row	0.071	0.193	0.211	0.061	0.076	-0.167	1.000

counting for 58.3% and 18.0% variability which explained up to 91.2% of total variability. The biplot (Fig. 1) which depicted both factor loading of growth and yield-attributing characters (Blue colour) and scores of treatment (Red colour) showed that days to 50% tasseling had a very high loadings on PC_1 wherein they were found to be diligently correlated to each other and scores (plot) 'Vivek Sankul 35', 'Vivek Sankul 37', 'Vivek Sankul 31', 'Satheya Makkai' and 'RCM 1-1'. On the other hand, numbers of rows/cob had strong loadings on PC_2 and were highly correlated to each other with associated score of 'Vivek Sankul 35' and 'Vivek Sankul 31' as evidently seen in biplot (Fig. 1).

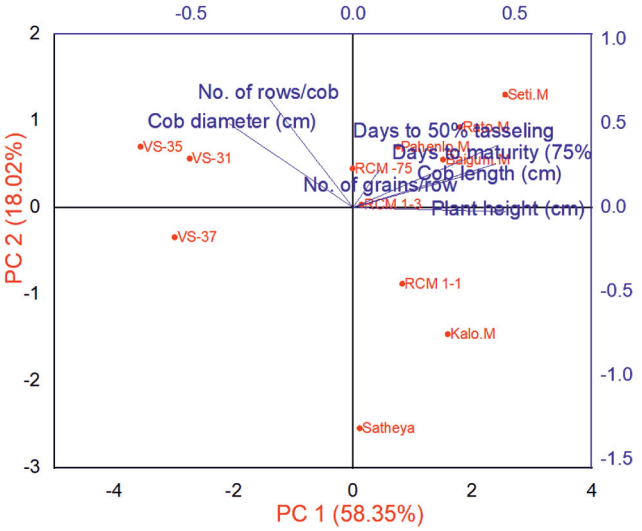

Fig. 1. Biplot formed by PC1 and PC2 showing the scores and loadings

Where, Sethi M, 'Seti Makkai'; Pahenlo M, Pahenlo Makkai; Rato M, Rato Makkai; Baiguni M, Baiguni Makkai; Kalo M, Kalo Makkai; VS-31, Vivek Sankul 31; VS-37, Vivek Sankul 37 and VS–35, Vivek Sankul 35

Economics

Different cultivars of maize exhibited a significant impact on their economics over the course of the study years under organic management conditions (Fig. 2). Maximum gross returns (117 × 10^3 ₹/ha), net returns (76.24 × 10^3 ₹/ha), returns/rupee invested (2.84), production efficiency (4.91 kg/ha/day) and profitability (208.8 ₹/ha/day) were recorded in 'Vivek Sankul 35' as compared to the other cultivars except 'Vivek Sankul 31', 'Vivek Sankul 37' and 'Sethi Makkai' but significantly higher than the remaining cultivars. Higher grain and stover yields of these resulted in higher profits, as also reported by (Babu *et al*., 2016).

It can be inferred that short-duration maize cultivar 'Vivek Sankul 35' was found most promising in terms of productivity and profitability and may be recommended for cultivation by farmers of Sikkim Himalayas and similar agroecoregions under organic production.

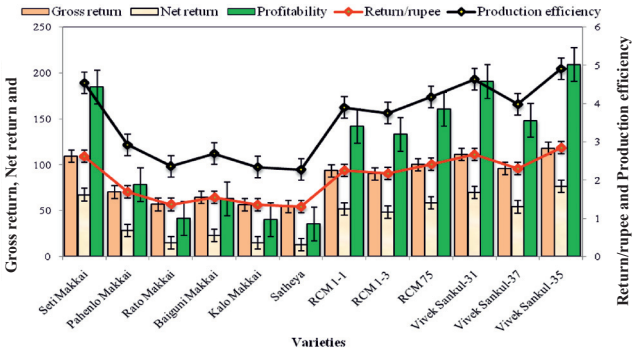

Fig. 2. Economic effectiveness of different varieties of maize under organic production system (mean data of 2 years)

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