

Influence of mulching on productivity, root growth and weed dynamics of maize (*Zea mays*)–based cropping systems

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ABSTRACT

An experiment was conducted at Basar, during 2008–11 on maize (*Zea mays* L.)–based cropping systems, to evaluate the production, root growth and weed dynamics with and without mulch. The productivity of sequential crops was 18–35% higher with mulch application than no mulch. However, the highest maize yield (4.25 t/ha) was obtained with maize–groundnut (*Arachis hypogaea* L.) cropping system, followed by maize–pea (*Pisum sativum* L.; 4.24 t/ha). Similarly, yield of sequence crop was the highest with Frenchbean (*Phaseolus vulgaris* L.; 4.91 t/ha). Maize–equivalent yield and production efficiency were the highest with maize–Frenchbean system (10.1 t/ha and 42.4 kg/ha/day respectively). Land-use efficiency was found maximum with maize–Indian mustard [*Brassica juncea* (L.) Czernj. & Cosson] system (71.9%) followed by maize–groundnut system. Root length, dry weight, volume number and density were recorded higher with groundnut (50.2 cm, 6.9 g/plant, 43.3 cc, 20.8 and 160.5 mg/cc respectively) followed by Indian mustard and lowest with Frenchbean. However, specific root length was highest with pea (12.0 cc/g). Density, dry weight, index and persistency of weed were the highest with maize–fallow, followed by maize–Frenchbean system. However, weed-smothering efficiency was the maximum with maize–groundnut (59.4 %), followed by maize–Indian mustard system (58.6%). Mulched plot registered the least said weed parameters with 65% weed-smothering efficiency. Soil-moisture content 30, 60 and 90 days after sowing (DAS) was higher with maize–groundnut system, followed by maize–Indian mustard system, and between the mulch, no mulched plot had considerably lower soil moisture than the mulched ones.

Key words : Crop production, Cropping systems, Maize, Mulch, Root characteristics, Soil moisture, Weed dynamics

Maize is the second largest cereal crop being grown in Arunachal Pradesh after rice with acreage of 0.50 million ha. But traditionally, both these crops are grown as mono crops and land is kept fallow after harvesting of these crops (Choudhary *et al.*, 2013). Maize is being grown in upland suffers from soil-moisture stress during early and the later stages of development due to poor moisture retention in upland. Thereafter second crop is quite not possible due to non- adoption of moisture-conserving techniques (Saha and Ghosh, 2010). Poor adoption of water-conservation measures is one of the important factors, which restricts agriculture production and reduces the land-use efficiency in the region. Application of available crop residues offers an opportunity to enhance crop production, soil and water conservation, weed management and in-

crease cropping intensity and productivity. Recurring of weeds is another limiting factor in the crop production, as they reduce the crop yield and deteriorate the quality of produce; and hence reduce the market value of the turn out (Arif *et al.*, 2006). In addition, weeds reduce the soil fertility, available moisture and nutrients, compete for space and light with crop plants, which result in yield reduction (Khan *et al.*, 2004).

Mulches show positive effects on moisture, heat, air regime of the soil and also restrict the idle evaporation and weed growth (Bu *et al.*, 2002; Kumar *et al.*, 2012). The more favourable water regime manifested in higher yields makes mulching not only soil protective, but economically favourable as well (Yang *et al.*, 2006). Crops grown during the post-rainy season in eastern Himalaya's experiences water deficit (Saha and Ghosh, 2010). Cropping pattern could be improved by using legumes in rotation with cereals. During moisture deficit the ability of a plant to change its root distribution in the soil is an important

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mechanism for mitigating moisture stress. Legume like pea, Frenchbean and groundnut are gaining attention of farmers owing to their high market demand, production potential and adoption to water deficit. Keeping these in view, maize-based cropping systems were evaluated with the objective of analyzing the potential for improving the productivity of maize-based cropping systems through mulch application and its impact on root growth and weeds.

MATERIALS AND METHODS

The field experiment was carried out at the research farm of ICAR Research Complex for NEH Region, Arunachal Pradesh Centre, Basar, located at West Siang District of Arunachal Pradesh, extends 27° 95'N and 94° 76'E, 631 m above mean sea-level. The area falls under humid, subtropical climate. The daily temperature of the experimental site during the years varies widely between minimum 4°C and maximum 35°C, with an average rainfall of 2,311.8 mm. The distribution of rainfall during the experimental period is presented in Fig. 1. The soil was clay, acidic (pH 5.3), and high in organic carbon (Walkaley and Black, 13.2 g/kg), available nitrogen (N; alkaline permanganate, 96.9 mg/kg), available phosphorus (P; Bray, 5.2 mg/kg) and available potassium (K; ammonium acetate, 105.3 mg/kg). The experiment was laid out in split-plot design and replicated thrice for 3 consecutive years (2008–09 to 2010–11). Maize was grown during the rainy season with recommended cultural practices. Recommended N, P and K were applied through urea, single superphosphate and muriate of potash respectively. Maize yield was recorded from each plot separately with net plot area of 5.0 m × 3.0 m and grain yield was recorded at 15% seed moisture. Pea, toria, Frenchbean and groundnut were grown during post-rainy season after harvesting of maize and details are given in Table 1. Sequential crops were considered as main plot and mulched plot as subplot. Mulch practices, viz. no mulch and paddy straw mulching at 5.0 t/ha, was placed with the gross plot area of 5.4 m × 3.6 m. Seeds were dibbled after land preparation at desired depth. Mulch materials were applied in the field just after

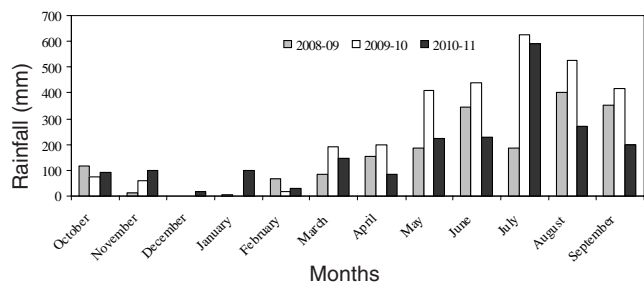


Fig. 1. Rainfall distribution during the experimental period (2008–09, 2009–10 and 2010–11)

Table 1. Package of practices followed for different crops during the study period

Crops	Variety	Planting date			Nitrogen scheduling*	Spacing (cm × cm)	Fertilizer dose (kg NPK/ha)	Harvesting date		
		2008–09	2009–10	2010–11				2008–09	2009–10	2010–11
Maize	Allrounder	2 May	14 May	10 May	30 kg at basal, 25 kg 25 days after sowing (DAS) and rest 25 kg 50 DAS	60 × 30	80:60:40	17 September	22 September	22 September
Pea	Azad pea 1	8 October	10 October	11 October	20 kg basal dose	30 × 10	20:60:30	25 January	27 January	29 January
Indian Mustard	M 27	8 October	10 October	11 October	25 kg basal and 25 kg 30 DAS	30 × 10	50:60:30	26 February	28 February	28 February
Frenchbean	Anupama	8 October	10 October	11 October	20 kg basal dose	45 × 15	20:60:30	2 February	5 February	4 February
Groundnut	JS 46	8 October	10 October	11 October	20 kg basal dose	45 × 15	20:60:30	28 February	30 February	30 February

*P and K were applied basal (just before the sowing); farmyard manure at 8.0 t/ha was applied 20 days prior to sowing

sowing of sequential crops and it remained in the field till the end of harvesting, but not in case of maize. Other inter-cultural operations were followed as per scientific cultivation practices for each crop.

The yields of various crops of the respective cropping systems were recorded and converted to maize-equivalent yield based on the price prevailed in the local market. Per day productivity (production efficiency; kg/ha/day) was calculated on the basis of maize-equivalent yield of the system by dividing to the total duration of crops in the sequence (Tomar and Tiwari, 1990). Root parameters of sequential crops were measured with the help of soil cores of 8 cm diameter at 60 days after sowing (DAS) to the depth of 60 cm in 15 cm increments and data presented are sum of 0–60 cm. Similarly, observations on weeds were recorded at 60 days after sowing (DAS) with the help of a quadrat 0.5 m × 0.5 m placed randomly at 3 spots in each plot. The data on weeds were subjected to square root transformation ($\sqrt{x+0.5}$) to normalize their distribution. Weed-smothering efficiency was calculated using weed dry weight. Weed-persistency index was recorded as:

Weed persistency index = [(dry weight of weed in treated plot/dry weight of weed in control plot) × (weed count in treated plot/weed count in control plot)]

Soil-moisture content was measured gravimetrically at 30, 60 and 90 days after sowing (DAS) up to 20 cm soil depths. Statistical analysis was carried out to know the variance for different parameters, using standard statistical package (SAS 9.2) and significance was denoted at $P < 0.05$ level.

RESULTS AND DISCUSSION

In most of the cases, the effect of year and/or year × cropping system and/or year × mulch, cropping system ×

mulch was not significant; therefore combined results are presented.

Productivity and equivalent yield

Yield of maize and sequential crops were significantly influenced by maize-based cropping system (Table 2). Maize–groundnut cropping system gave higher maize yield in 3 consecutive years, followed by maize–pea. The biological nitrogen-fixing ability of leguminous crops not only supplied the additional nitrogen but also helped the plant to provide more macro- and micronutrients through the increment in biological properties of soil (Cantero-Martinez *et al.*, 2003; Angas *et al.*, 2006; Azam *et al.*, 2008). Mulched treatment of sequential crop registered higher yield with 35% in groundnut, 26% in Indian mustard, 24% in pea and 18% in Frenchbean over no-mulched plot (Table 2). The maize-equivalent yield was recorded 154.6% higher with maize–frenchbean with mulch, followed by 131.2% without mulch, Groundnut with mulch recorded 117.6% higher maize-equivalent yield (MEY). However, lowest maize-equivalent yield (MEY) was harvested with maize–fallow. It was lucid from the study that taking up the second crops is essential in north-eastern Himalaya, as it not only increases the cropping intensity but also generates employment opportunity to the tribal farmers. In general, mulched plot took little more time to harvest due to available soil moisture and favourable growth condition which prolonged the life-cycle of crop. However, among the different systems, maize–Indian mustard system took highest duration to harvest.

Production and land-use efficiency

The cropping systems significantly influenced the production efficiency (Table 2). The highest production effi-

Table 2. Yield, production and land-use efficiency as influenced by maize based cropping systems (mean of 3 years)

Treatment	Maize yield (t/ha)	Yield of cropping system (t/ha)	Maize equivalent yield (t/ha)	Duration of cropping system (days)	Production efficiency (kg/ha/ day)	Land-use efficiency (%)
<i>Cropping system</i>						
Maize–pea	4.24	2.48	7.96	240.0	33.2	65.8
Maize–Indian mustard	4.11	1.38	7.56	262.5	28.8	71.9
Maize–Frenchbean	4.21	4.91	10.10	238.0	42.4	65.2
Maize–groundnut	4.25	1.67	8.43	258.0	32.7	70.7
Maize–fallow	4.16		4.16	135	30.8	37.0
SEm±	0.03		0.15		1.2	2.0
CD (P=0.05)	0.08		0.45		3.2	5.5
<i>Mulch</i>						
Without mulch		2.34	8.03	247.0	32.7	67.7
With mulch		2.88	8.99	252.3	35.8	69.1
SEm±			0.11		0.8	1.3
CD (P=0.05)			0.32		2.1	3.5

Price of produce as per the prevailing market price (₹/kg): Maize, 10; pea, 15; mustard, 25; frenchbean, 12; groundnut, 25

ciency was recorded in maize–Frenchbean with mulch, followed by without mulch. However, the least production efficiency was recorded with maize–Indian mustard system, followed by maize–fallow system. Crop duration and market price of the produce greatly influences the production efficiency (Mukherjee, 2010). The land-use efficiency was found higher on maize–Indian mustard system with mulch (72.6%), followed by without mulch (71.2%) and maize–groundnut with mulch (69.9%). This was owing to higher crop duration, which in turn recorded the highest land-use efficiency and efficient utilization of land over other systems. Similar finding was observed by Saha and Ghosh (2010) in rice-based cropping system. Poor utilization of land resulted into the least land-use efficiency on maize–fallow cropping system (37.0%).

Root growth

Although direct comparison of root-growth measurements among various crops was not possible due to differences in row spacing, planting density and management practices, a few observations about the root characteristics were noted. Root growth significantly influenced with sequential crop and placed mulch (Table 3). The highest root length, root dry weight, root volume, root numbers and root density were recorded with groundnut, followed by pea and Indian mustard. However, these parameters were lower with Frenchbean. Specific root length was higher with pea and root length density was higher with Indian mustard. It is evident that groundnut, pea and Indian mustard had the ability to change and adopt against the moisture-deficit condition and proliferation of root growth.

There were distinct differences among the species on the way they performed in rainfed condition. Groundnut, Indian mustard and pea had a greater proportion of their

root systems deeper in the soil profile than Frenchbean (Merril *et al.*, 2002). Groundnut and Indian mustard responded to rainfed conditions by increasing the proportion of roots deeper in the soil, whereas Frenchbean maintained the maximum of the roots near the soil surface regardless of water deficit. Groundnut and Indian mustard had a greater length, dry weight, number, volume and length density of root than Frenchbean, which helped in better soil exploration and water extraction (Benjamin and Nielsen, 2006). Between the placed mulch and without mulch, it is evident from the Table 3 that all the root parameters were recorded higher with mulch treatment except root numbers and specific root length. The higher values of root parameters in mulch might be due to loose soil and sufficient moisture, whereas root number and specific root length were higher when no mulch was applied, might be due to lower availability of moisture and compactness of soil forced the plant to produce more roots, rather go in deep. Interestingly, interaction of sequence crop and mulch had no significant effect on the root-growth parameters.

Weed dynamics

The sequential crops and mulch treatments significantly influenced the weed dynamics (Table 4). Density and dry weight of weed were higher with maize–fallow, followed by maize–Frenchbean. However, weed-smothering efficiency was the highest with maize–groundnut followed by maize–Indian mustard and least with maize–Frenchbean. Weed index was higher on maize–fallow and the lowest with maize–groundnut. Similarly, weed-persistence index was higher with maize–fallow (60.6%) followed by maize–Frenchbean, but lower persistence was observed with maize–groundnut. The lower density and dry weight of weed in groundnut as sequential crop might be due to

Table 3. Root growth as influenced by mulch in maize-based cropping systems (mean of 3 years)

Treatment	Root length (cm)	Root dry weight (g/plant)	Root volume (cc)	Root numbers	Root density (mg/cc)	Specific root length (cc/g)	Root length density (cm/cc)
<i>Cropping system</i>							
Maize–pea	46.2	3.8	42.7	12.7	90.1	12.0	1.08
Maize–mustard	46.0	4.9	38.0	16.5	130.5	9.4	1.22
Maize–Frenchbean	34.5	2.9	36.5	10.2	80.8	11.9	0.95
Maize–groundnut	50.2	6.9	43.2	20.8	160.5	7.3	1.16
SEM±	1.2	0.2	1.4	0.9	5.8	0.6	0.03
CD (P=0.05)	3.7	0.5	4.0	2.7	17.3	1.7	0.09
<i>Mulch</i>							
Without mulch	40.3	4.1	38.6	16.8	107.7	10.3	1.1
With mulch	48.1	5.2	41.6	13.2	123.3	9.9	1.2
SEM±	1.9	0.5	1.3	1.3	10.3	6.7	0.04
CD (P=0.05)	5.7	NS	NS	NS	NS	NS	NS

better canopy coverage and fast growth, which facilitated to cover the ground earlier than the others. Sequential crops reduced the radiation translocation, and restricted the emergence and growth of weed (Ghosh *et al.*, 2006). However, fallow land had more weed species and dry weight, followed by Frenchbean.

Use of mulch restricted the weed growth and significantly lowered the weed parameters under mulching. Density, dry weight, index and persistency index of weed were lower under mulched plot (7.5 m², 4.4 g/m², 20.6 and 11.6% respectively), whereas mulched plots had 65% higher weed-smothering efficiency than the without mulch plot. Reduced weed germination and infestation by restricting the penetration of solar radiation under mulch resulted in higher weed-smothering efficiency. But no mulching induced the germination of weeds, therefore weed-smothering efficiency was comparatively lower (Hiltbrunner *et al.*, 2007; Patel *et al.*, 2009). Placement of mulch reduced the weed species and provided the congenial condition for crops to grow and develop (Moonen and Barberi, 2004).

Weed-smothering efficiency (WSE) and weed dry weight had significant positive linear relation (Fig. 2a) with coefficient of determination (R^2) of 0.87. This clearly indicated that with the increase in weed dry weight, WSE decreased. Similarly, weed dry weight and weed-persistency index had positive linear relation with $R^2=0.95$ (Fig. 2b). It indicated that, with the increase in weed dry weight, weed-persistency linearly increased. But WSE and weed persistency index has quadratic relation with $R^2=0.91$. It showed that as WSE increased, the weed-persistency decreased exponentially. However, interaction of cropping system and mulch were significant at $P=0.05$ for WSE and weed-persistency index (Fig. 2c).

The interaction effect of maize-based cropping system and mulches revealed that the highest weed-smothering efficiency was obtained with maize-groundnut with mulch which was comparable with maize-Indian mustard cropping system with mulch, whereas the lowest was recorded with maize-fallow without mulch (Table 5). In contrary to these, weed-persistency index was the lowest with maize-groundnut with mulch.

Table 4. Weed dynamics as influenced by mulch in maize-based cropping systems (mean of 3 years)

Treatment	Weed density (#/m ²)	Weed dry weight (g/m ²)	Weed-smothering efficiency (%)	Weed index (%)	Weed-persistency index (%)	Consumptive water (mm)	Water-use efficiency (kg/ha/mm)
<i>Cropping system</i>							
Maize-pea	9.4 (92.3)	5.5 (31.0)	43.5	21.2	33.0	1,062.3	7.1
Maize-Indian mustard	8.7 (79.5)	4.7 (22.7)	58.6	25.2	20.7	1,074.6	6.7
Maize-Frenchbean	9.9 (102.2)	5.8 (34.7)	46.8	-	39.4	1,075.3	8.9
Maize-groundnut	8.2 (70.2)	4.7 (22.2)	59.4	16.6	18.2	1,047.9	7.5
Maize-fallow	11.4 (135.2)	6.2 (39.8)	27.4	58.8	60.6	1,100.6	3.8
SEm±	0.2	0.2	0.03		0.02		0.5
CD (P=0.05)	0.6	0.5	0.08		0.07		1.4
<i>Mulch</i>							
Without mulch	11.6 (134.9)	6.4 (41.0)	29.3	28.2	57.2	1,056.4	5.5
With mulch	7.5 (56.9)	4.4 (19.1)	65.0	20.6	11.6	1,070.4	4.2
SEm±	0.3	0.3	0.04		0.05		1.9
CD (P=0.05)	0.9	0.6	0.11		0.14		5.2
C × M	NS	NS	*		**		NS

*Figure in parentheses are original value and normal values are square root transformed value with $\sqrt{x+0.5}$

Table 5. Effect of cropping system and mulch on weed-smothering efficiency and weed persistency index

Treatment	Weed-smothering efficiency (%)		Weed-persistency index (%)	
	Without mulch	Mulch	Without mulch	Mulch
Maize-pea	12.7	70.9	55.7	10.3
Maize-Indian mustard	40.0	74.5	34.7	6.7
Maize-Frenchbean	37.5	54.5	64.6	14.2
Maize-groundnut	50.9	69.1	30.9	5.5
Maize-fallow	0.0	56.4	100.0	21.2
	SEm±	CD (P=0.05)	SEm±	CD (P=0.05)
C × M	3.8	11.5	5.9	17.9

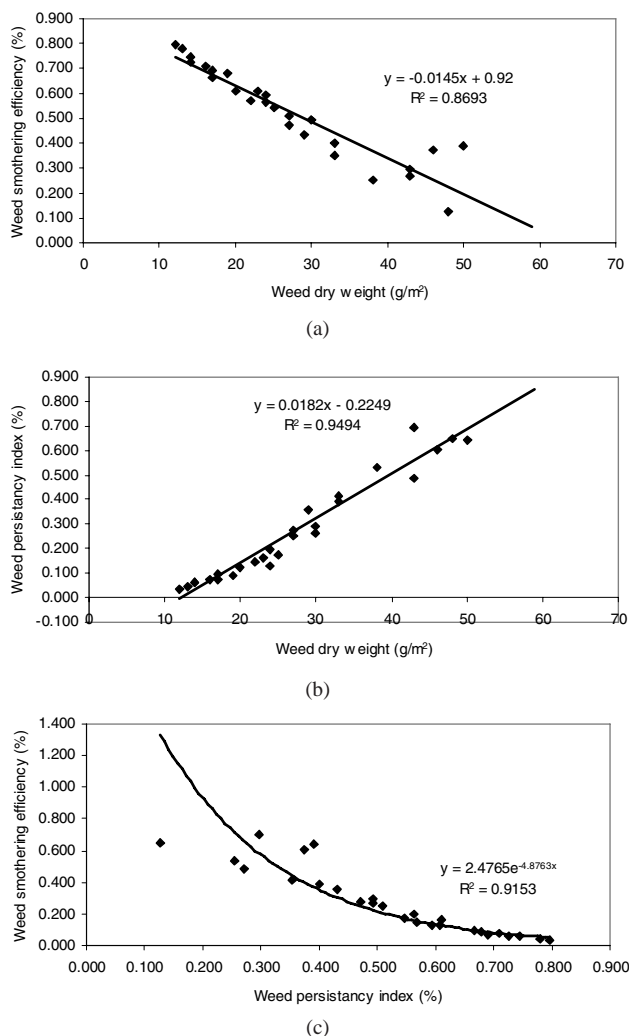


Fig. 2. Relationship of (a) weed dry weight and weed-smothering efficiency, (b) weed dry weight and weed-persistence index, and (c) weed-smothering efficiency and weed-persistence index with respect to maize-based cropping system and mulch

Soil-moisture content and consumptive use

Soil-moisture content significantly affected by sequential crops and mulches in maize-based cropping system (Fig. 3). The highest soil-moisture content at 30, 60 and 90 DAS was recorded with groundnut, followed by Indian mustard. However, lowest-moisture content was observed on fallow land at 30 DAS, whereas at 60 and 90 DAS Frenchbean had lowest soil moisture. These might be due to better canopy coverage of groundnut and Indian mustard, which did not allow the solar radiation to had direct contact with the soil surface and avoided the evaporation loss. However, during 60 and 90 DAS, lower moisture in Frenchbean and pea was observed than fallow land; might be due to thin canopy coverage allowed to higher evaporation from soil surface, and extensive root-system helped in extraction of water from different layer. But, fallow land

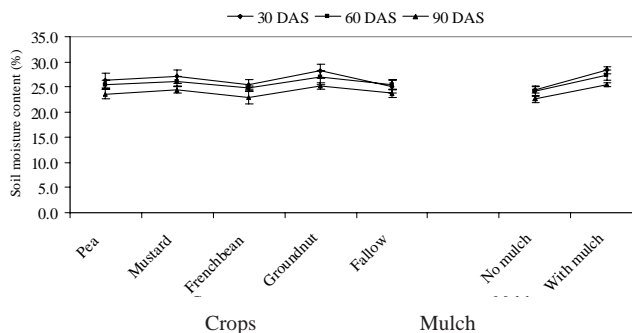


Fig. 3. Depth-wise soil-moisture content in maize-based cropping system and mulch (error bar shows \pm standard deviation; $n=5$) (DAS, days after sowing)

has only contributed to evaporation loss. Our findings confirm the results of Gan *et al.* (2009).

The maximum consumptive use of water was recorded for maize–fallow system, followed by maize–Frenchbean and maize–Indian mustard system (Table 4). However, the lowest consumptive use of water was obtained with maize–groundnut system. Consequently, water-use efficiency was registered 136.5% higher with maize–Frenchbean cropping system, followed by maize–groundnut cropping system (97.1%) than the maize–fallow cropping system. Similar results were also reported by Kaneko *et al.* (2004) and Sarkar and Goswami (2007).

Mulch recorded comparatively higher soil moisture 30, 60 and 90 DAS over without mulch. It is evident from Fig. 3 that at 30 DAS mulch had 15.9% higher soil moisture, whereas at 60 and 90 DAS mulch had 13.7 and 12.4% higher soil moisture. Mulch primarily affected the field microclimate by modifying the radiation budget of the surface and suppressing soil water evaporation. These microclimate factors strongly affect the soil temperature and moisture in the root zone, which in turn influenced the plant growth and productivity (Korir *et al.*, 2006). Use of mulch also helped in better utilization of water and recorded 31% higher water-use efficiency over without mulch.

It was concluded that the maize–Frenchbean cropping system has highest maize-equivalent yield and production efficiency. But, maize–Indian mustard system used land more effectively. Use of mulch in the sequential crops not only increased the crop yield but also helped in better root growth for exploitation of soil resources and better soil-moisture content and weed management.

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