Indian Journal of Agronomy **66** (3): 333–338 (September 2021)

Research Paper

Maize (*Zea mays*)-based cropping system on raised beds influenced the productivity, soil quality and profitability in North-East India

A.S. PANWAR[1], SUBHASH BABU[2], NOOPUR KOHIMA[3] AND SANJEEV KUMAR[4]

ICAR Research Complex for North Eastern Hill Region, Umiam, Meghalaya 793 103

Received: December 2020; Revised accepted: September 2021

ABSTRACT

A field experiment was conducted for 4 years (2013–17) at Umiam, Meghalaya, India, to study the performance of different maize- based cropping sequences on permanent raised beds in valley lowland under a mid-hill altitude of North-East India. The treatment consisted of 9 maize-based cropping sequences (maize–greengram [*Vigna radiata* (L.) R. Wilczek], maize–rice bean [*Vigna umbellata* (Thunb) ohwi & ohashi], maize–rajmash [*Phaseolus vulgaris* L.], maize–pea [*Pisum sativum* L.], maize–groundnut [*Arachis hypogaea* L.], maize–lentil [*Lens culinaris* Medik], maize–linseed [*Linum usitatissimum* L.], maize–mustard [*Brassica juncea* L.], and maize–toria [*Brassica compestris* var. toria L.), on raised beds with legume and non-legume crops. The inclusion of legume crops in the cropping sequence significantly enhanced the system productivity as compared to non-legume crops. Amongst the various crop combinations, maize–pea gave the highest production efficiency (65.93 kg/ha/day), followed by maize–rajmash (65.70 kg/ha/day), the lowest being with maize–toria (34.22 kg/ha/day). Land-use efficiency was higher with maize–pea and maize– lentil systems. The highest cost of cultivation was recorded in maize–rice bean and maize–rajmash, but the maximum net returns were realized from maize–pea (₹56,964/ha) and maize–rajmash (₹42,118/ha) sequences. The sustainable yield index (SYI) and sustainable value index as well as a benefit: cost ratio was also higher with maize–pea and maize–rajmash cropping sequences. Maize–mustard registered the highest nutrient uptake but the residual fertility status was more with maize–pea cropping system. The soil quality improved due to the inclusion of legumes as compared to non-leguminous crops in maize-based cropping sequence. The surfaceplot analysis portrayed the positive relationship between soil quality parameters like SOC (r = 0.10), available N (r = 0.27), available phosphorus (r = 0.22) and available potassium (r = 0.22) with SYI.

***Key words*:** Intensification, Production efficiency, Profitability, Soil fertility, Sustainability.

Maize is the second most important crop, occupying ~0.261 million ha area with less than 2.0 t/ha productivity in North-Eastern states of India (Babu *et al.,* 2020a). In the North-Eastern Himalayan Region (NEHR), maize production plays a significant role in ensuring food security and is used both for direct consumption and as well as for second-cycle produce in piggery and poultry farming (Ansari *et al.,* 2017; Babu *et al.,* 2020b). The productivity of rainfed monocropping systems is a very low and high-risk economic activity. Therefore, sustainable intensification is a viable option to improve production and soil quality and optimize the benefits that can be derived from making better use of available natural resources (Panwar *et al.,* 2006). In this region, the field remains fallow and monocropped due to moisture stress under upland situations. But in the valley lowland, high rainfall during monsoon period causing water stagnation or moisture higher than saturation point which does not allow crops other than rice to grow even during the winter (*rabi*) season. These valley lands can be used for the growing of any type of crop with the adoption of suitable land configuration, i.e. permanent raised bed system (Panwar, 2006). This permanent raised bed system helps to bring moisture at the optimum level, required for the proper growth and development of crops and is considered to be a useful technology for proper land and water management. On these raised beds, maize can be successfully grown in sequence with other crops to en-

[2]**Corresponding author's Email:** subhiari@gmail.com
[1]Director, ICAR-Indian Institute of Farming Systems Research, Modipuram-250 110, Uttar Pradesh, [2]Scientist, Division of Agronomy, ICAR-Indian Agricultural Research Institute, New Delhi-110 012, [3]Ph.D. Scholar, Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu, Jammu-180 009, [4]Ex-M.Sc. Scholar, Department of Soil Science and Agricultural Chemistry, College of Agriculture, Central Agricultural University, Imphal 795 004, Manipur

hance productivity and profitability, besides judicious use of excess water. French bean is also a promising candidate in a hilly region for improving food and nutritional security (Kohima *et al.,* 2019) and diversification (Panwar *et al.,* 2019). Maize with a legume cropping system has been recorded with significantly improved soil health and farm productivity as compared to the sole maize system (Yadav *et al.,* 2018; Singh *et al.,* 2021). Thus, not only the number of crops but the types of crops included in the cropping sequence need to be identified to enhance production and profitability. Since not much information is available on the sustainability of cropping systems on raised beds in lowland areas, an experiment was undertaken to find out the possibility of intensification and diversification in low land areas under high rainfall zone of mid-hill altitude of North-east India.

MATERIALS AND METHOD

The field experiment was conducted from 2013–14 to 2016–17 at the ICAR Research Complex for North Eastern Hill Region, Umiam, Meghalaya, India (25°41' N, 91° 63' E, 980 m above mean sea level). The area falls under the mild tropical hill zone and the climate is per-humid. The daily temperature during the year varies widely between 2.5°C (January) and 32.5°C (August). The region receives an average rainfall of 2,439 mm, with a high degree of temporal and spatial variations. An 80% of the annual rainfall is received during April – October. The soil was Haplaquant having *p*H 5.4, organic carbon 1.89%, available N (alkaline permanganate N, 245 kg/ha), available P (8.7 kg/ha), and K (ammonium acetate K, 265 kg/ha). Treatment comprised 9 maize-based cropping sequences, *viz.* maize–green gram, maize–rice bean, maize–rajmash, maize–pea, maize–groundnut, maize–lentil, maize–linseed, maize– mustard, and maize–toria. The sequences were evaluated in randomized block design with 3 replications on permanent raised beds of 4 m × 5 m size. Maize variety 'RCM 75' was sown in the first week of April while 'PD–1', 'RCRT 39', 'MLS', 'Azad Pea', 'ICGS-76', 'AVT21', 'Parvati', 'Varuna', and 'TS-38' varieties of green gram, rice bean, *rajmash*, pea, groundnut, lentil, linseed, mustard, and *toria*, respectively, were grown in *rabi* (winter) season. After harvesting of maize, permanent raised beds were spaded thoroughly to prepare the fine seedbed and second crops were sown as per their optimum time of sowing. Maize yield was recorded from a net plot area of 20 m^2 at 14% seed moisture. Groundnut, *rajmash*, rice bean, and greengram were sown in the second week of August, while pea, lentil, linseed, mustard, and *toria* were sown in the second week of October. All the recommended package of practices were followed for optimum growth and yield of crops. Staking was done for pea and rajmash at appropriate stages to prevent/minimize lodging. Fertilizer was applied @ 80 Kg N + 60 kg P_2O_5 + 40 kg K_2O to maize; 60 Kg N + 60 kg P_2O_5 + 40 kg K_2O to all non-legume and *rajmash* crop, while 20 Kg N + 60 kg P_2O_5 + 40 kg K_2O were given to legume crop. Nitrogen, phosphorus, and potassium as per recommendations were applied through urea, single superphosphate, and muriate of potash, respectively. The crops were harvested as and when they matured and their yield was recorded.

The yield of *rabi* crops was converted into maize-equivalent yield (MEY) by converting the yield into economic value based on the prevailing price in local market. The cost of raised bed preparation was added to the cost of cultivation in the first year and maintenance cost was added during subsequent years and at the end of the 4th year, the average of the total cost was calculated. Net returns, benefit: cost ratio (B : C), production efficiency were worked out for all the cropping sequences, and a mean of 4 years was presented. The sustainable yield index (SYI) and sustainable value index (SVI) were calculated as per Singh *et al*. (1990). Intensification in time was measured by calculating the value of land-use efficiency by dividing the total duration of a sequence by the number of days in a year and expressed as a percentage. Change in soil fertility status was studied after 4 years of experimentation.

RESULTS AND DISCUSSION

Crops growth and system productivity

The effect of crops on maize yield was significant. Plant height and number of leaves in maize were highest when it was grown after legumes as compared to non-legume ones. Amongst the legumes, the tallest plants were recorded with greengram followed by pea (Table 1). Maximum grains/cob were recorded with maize–pea and maize–rajmash, while the barrenness was more with maize–linseed and maize–mustard. The highest grain and straw yield per plant (147.81 and 628.40 g) was recorded with maize–pea and lowest was with maize–mustard system. Maize yield was significantly highest (2.88 t/ha) with maize–pea/rajmash, followed by maize–greengram cropping system. It might be owing to the effect of legumes in the system in improving soil fertility and productivity of succeeding crops (Lal, 2017; Babu *et al.,* 2020b). The lowest maize yield (2.26 t/ha) was recorded when grown after linseed which increased up to 0.6-0.7 t/ha with maize–legumes system might be owing to high nitrogen fixation and its availability compared to mustard or linseed (Table 2). Unlike maize yield, the highest biomass was harvested in pea (2.62 t/ha) followed by groundnut (2.34 t/ha), rajmash (2.10 t/ha), and linseed (1.61 t/ha). Based on pooled data of 4 years, the highest maize equivalent yield (MEY) was observed with maize–pea (9.09 t/ha), and maize–rajmash (7.55 t/ha) being significantly superior to the other cropping systems studied. Higher yield and price of produce in the system increased the MEY. Maize–linseed cropping was the next higher-yielding cropping sequence because of the higher market price of linseed. Despite the high price of *toria*, maize–toria could not give maize equivalent yield even comparable to maize–mustard due to lower yield level and an uneconomical by-product of *toria*. Inclusion of greengram, although increased maize yield but maize-equivalent yield was at par with maize–mustard cropping sequence.

Production and land-use efficiency

Production efficiency followed a trend similar to the total productivity of different crop sequences (Table 3). Maize–pea cropping sequence revealed higher production efficiency (70.93 kg/ha/day) being comparable with maize–rajmash (65.70 kg/ha/day). In the other cropping sequences, it varied from 34.22 to 56.23 kg/ha/day, and the lowest being in maize–toria mainly due to the low level of *toria* production in the system. The production efficiencies were 31.20 to 107.28% higher in maize-based cropping sequences as compared to maize–toria due to lower MEY. Maize–pea sequence being at par with maize–lentil recorded the highest landuse efficiency, because these sequences utilized land most efficiently. Maize– greengram and maize–toria were the most inferior in respect of landuse, as the land remained idle for almost 5 months in a year. The other cropping sequences used the land for 61-70 % period of the year, primarily due to the duration of second crops in cropping sequences.

Economic analysis

Economic analysis of various cropping systems revealed that the cost of cultivation varied with the crop grown and associated cultivation practices. The highest cost of cultivation was involved in maize–rice bean and maize–rajmash (₹37,965/ha) cropping sequence because of the

Table 1. Effect of maize-based cropping sequence on growth and yield of maize

Crop sequence	Plant height (cm)	Cobs/ plant	Grains/ cob	Barrenness (%)	Seed index (g)	Grain yield (g/plant)	Straw yield (g/plant)
Maize–green gram	354.3	1.1	412.3	8.2	30.8	138.1	561.3
Maize– rice bean	340.7	1.0	400.8	8.2	30.6	136.6	591.3
Maize–rajmash	345.3	1.1	416.8	7.5	30.6	142.5	592.6
Maize – pea	350.5	1.1	421.5	7.3	31.5	147.8	628.4
Maize –groundnut	345.3	1.0	405.5	8.3	30.5	132.7	584.3
Maize–lentil	345.3	1.1	400.7	7.8	30.3	126.3	590.2
maize – linseed	316.2	1.0	334.9	13.2	29.6	109.0	395.9
Maize–mustard	328.7	1.0	350.2	12.8	29.8	105.2	386.5
Maize–toria	336.0	1.0	385.2	10.3	30.1	118.0	425.7
SEm±	3.01	0.09	3.5	0.75	0.68	5.38	4.93
CD (P = 0.05)	7.5	NS	8.8	1.4	1.5	15.5	14.7

SEm ±: standard error of mean; CD critical difference; NS: non-significant

Table 2. Effect of maize-based cropping sequence on yield and maize-equivalent yield

Crop sequence	Yield (t/ha)								Average yield (t/ha)		MEY (t/ha)
	2013–14		2014–15		2015–16		2016–17				
	Kharif	*Rabi*	*Kharif*	*Rabi*	*Kharif*	*Rabi*	*Kharif*	*Rabi*	*Kharif*	*Rabi*	
Maize–green gram	2.45	1.05	2.65	1.22	2.99	1.21	3.05	1.45	2.78	1.23	5.31
Maize–rice bean	2.43	1.40	2.71	1.57	2.89	1.46	3.01	1.35	2.76	1.44	5.44
Maize–rajmash	2.47	1.43	2.37	2.03	3.02	2.38	3.47	2.56	2.83	2.10	7.55
Maize–pea	2.68	1.99	2.75	2.57	2.73	2.68	3.47	3.25	2.88	2.62	9.01
Maize–groundnut	2.56	1.75	2.35	1.96	2.82	2.18	3.28	3.47	2.75	2.34	6.51
Maize–lentil	2.55	1.23	2.49	0.85	2.62	1.32	3.46	1.42	2.78	1.20	5.12
maize –linseed	2.38	1.53	2.06	1.42	2.14	1.51	2.46	1.36	2.26	1.46	6.55
Maize–mustard	2.35	1.27	2.15	1.57	2.31	1.85	2.62	1.73	2.36	1.60	5.80
Maize–toria	2.32	0.65	2.25	0.86	2.47	1.05	2.65	0.93	2.42	0.87	4.29
SEm±	0.98	-	0.06		0.06		0.07	-	0.09	-	0.19
CD (P=0.05)	NS	-	0.12	-	0.14	-	0.18	-	0.24	-	0.54

SEm±: standard error of mean; CD: critical difference; NS: non-significant; MEY: Maize-equivalent yield; Kharif, rainy season; Rabi, winter season additional cost of staking for a climber of rice bean and *rajmash*. Maize–toria/greengram accounted for the lowest cost of cultivation, obviously owing to lower input requirements. The cost of cultivation for the other cropping sequences was lies between ₹32,470– 35,965/ha. Among different cropping systems, the maximum net returns were recorded in maize–pea (₹56,964/ha) followed by maize–rajmash (₹42,118/ha) indicated that multiple cropping systems with legume offer special yield and monetary advantages (Babu *et al.,* 2016; Singh *et al.,* 2021). Maize–linseed system gave the next higher net return (₹34,330/ha) because of the higher price of linseed in the market. Maize–toria gave the lowest net returns and hence cannot be suggested in maize-based cropping sequence on a permanently raised bed. The benefit: cost ratio of maize-pea (1.58), maize-rajmash (1.11), and maize–linseed (1.00) was also higher which indicated that it is quite safe to adopt these crop sequences to bring up the profitability of the sequences. Maize–greengram and maize–mustard registered similar benefit : cost ratio - (0.91 and 0.90), which were 11.11 and 9.90 % lower to maize–linseed cropping sequence. The sustainable yield index (SYI) and sustainable value index (SVI) were more with maize–pea (0.81 and 0.59) and maize–rajmash (0.68 and 0.38) while the lowest was with maize–toria and indicated that this sequence was not sustainable on the raised bed even as compared to maize–linseed cropping sequence.

Soil quality and correlation

Change in nutrient status over the year revealed that, legumes in maize-based cropping system improved the available nutrients like N, P, K, and soil organic carbon (SOC) as compared to non-legume crop sequence, which resulted in a decline up to 0.08% in SOC content in soil (Fig. 1). The improvement in nutrient status might be owing to the addition of nutrients by biological N-fixation of legume crop in the system. Maximum positive change in SOC was recorded with maize–pea (0.05%) and negative

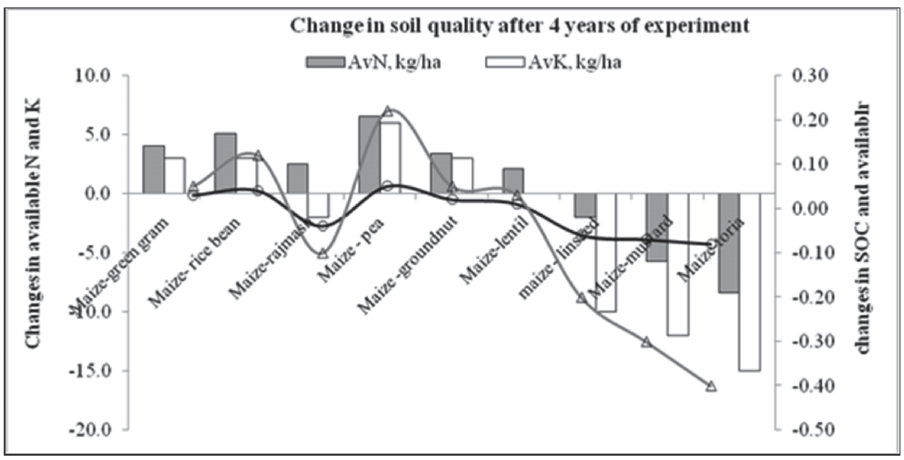

Fig. 1. Changes in soil quality status after 4 years of experiment as compared to initial soil quality status

Table 3. Production, efficiencies, and stability of maize-based cropping sequence

Crop sequence	Production efficiency (kg/ha/day)	Landuse efficiency (%)	Cost of cultivation (₹/ha)	Net return (₹/ha)	B:C ratio	Sustainable index	
						SYI	SVI
Maize–green gram	44.90	60.00	29,670	27,044	0.91	0.49	0.23
Maize–rice bean	42.82	68.22	37,965	21,786	0.57	0.50	0.14
Maize–rajmash	65.70	69.04	37,965	42,118	1.11	0.68	0.38
Maize–pea	70.93	72.33	35,965	56,964	1.58	0.81	0.59
Maize–groundnut	56.23	71.78	35,965	33,789	0.94	0.58	0.28
Maize–lentil	43.17	72.33	33,965	22,040	0.65	0.46	0.15
maize–linseed	51.61	69.59	34,475	34,330	1.00	0.60	0.34
Maize–mustard	45.70	70.96	32,470	29,529	0.91	0.54	0.25
Maize–toria	34.22	61.64	29,670	17,616	0.59	0.39	0.10
SEm±	-	-	298	381.7	-	-	-
CD (P =0.05)	-	-	876	1145	-	-	-

SEm±: standard error of mean; CD critical difference; SYI: Sustainable yield index; SVI: Sustainable value index B:C ratio: Benefits to cost ratio

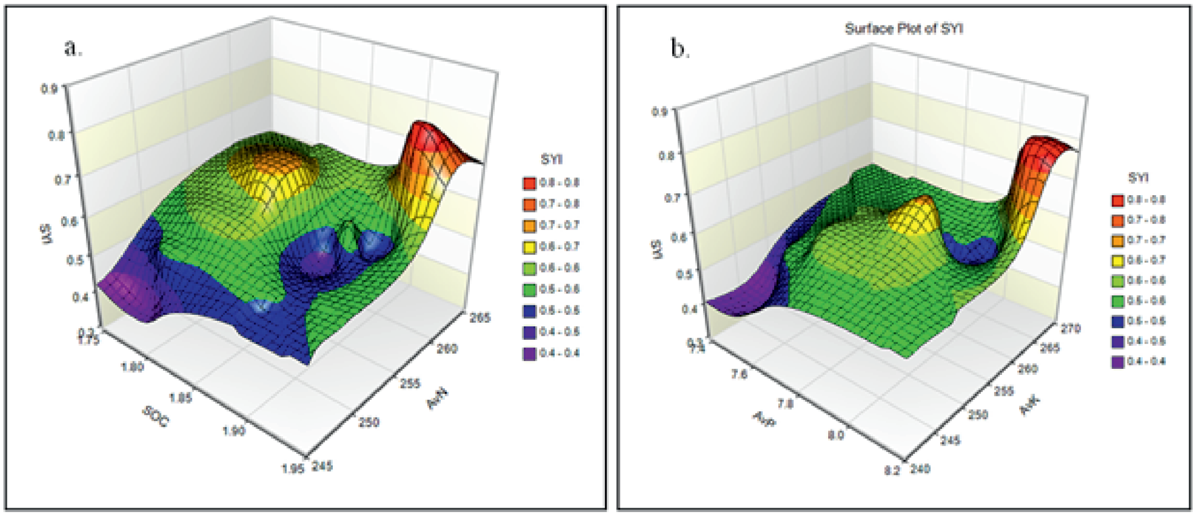

Fig. 2. D surface plots of relationship (*r*) between (a) soil organic carbon (SOC, %) and available nitrogen (Av. kg/ha) (AR) with sustainable yield index (SYI) and (b) available phosphorus (Av. P, kg/ha) and available potassium (Av. K, kg/ha) after four years

was with maize–toria (–0.08) crop sequence. Soil status with respect of N, P, and K improved excepting nitrogen in maize-linseed and maize–mustard/toria cropping sequence. Maize–pea sequence showed a significant addition of available N (6.5 kg/ha) over the initial status, indicating that inclusion of legume crop may help in stabilizing the crop yield by improving soil fertility in long term (Panwar and Munda, 2007; Singh *et al.,* 2021). Maximum reduction in soil nitrogen content was observed with maize–toria (8.5 kg/ha) cropping system. A similar trend was also recorded in the case of availability of P and K. These results are following those of Singh *et al.* (2021) who reported that maize and mustard being heavy feeders exhausted the soil fertility more than legumes. The surfaceplot analysis portrayed the positive relationship between soil quality parameters like SOC (r = 0.10), available N (r = 0.27), available phosphorus (r = 0.22) and available potassium (r = 0.22) with sustainable yield index (SYI) (Fig. 2).

Thus, it can be concluded that the growing of legume (pea) after maize is superior in terms of improvement in soil fertility and sustainability in crop yield. Maize–pea was more productive and sustainable. Amongst the non-legumes, maize–linseed sequence was found promising as well as higher yielder, and hence these cropping sequences can be adopted for crop diversification and intensification on raised beds under a mid-hill altitude of North-east India.

REFERENCES

Ansari, M.A., Choudhary, B.U., Prakash, N. and Rajkhowa, D. J. 2017. Comparative performance of maize (*Zea mays* L.) genotypes on productivity, quality, root dynamics and profitability in North Eastern Himalayan Region of India. *Bangladesh Journal of Botany* **46**(1): 195–202.

Babu, S., Singh, R., Avasthe, R.K., Yadav, G.S., Das, A., Singh, V.K. and Mohapatra, K.P., Rathore, S.S., Chandra, P. and Kumar, A. 2020b. Impact of land configuration and organic nutrient management on productivity, quality and soil properties under baby corn in Eastern Himalayas. *Scientific Reports* **10**(1): 1–14.

Babu, S., Mohapatra, K.P., Das, A., Yadav, G.S., Tahasildar, M., Singh, R., Panwar, A.S., Yadav, V. and Chandra, P. 2020a. Designing energy-efficient, economically sustainable and environmentally safe cropping system for the rainfed maize–fallow land of the Eastern Himalayas. *Science of The Total Environment* https://doi.org/10.1016/j.scitotenv.2020.137874

Babu, S., Singh, R., Avasthe, R.K., Yadav, G.S. and Rajkhowa, D.J. 2016. Intensification of maize (*Zea mays*)-based cropping sequence in rainfed ecosystem of Sikkim Himalayas for improving system productivity, profitability, employment generation and energy-use efficiency under organic management condition. *Indian Journal of Agricultural Sciences* **86**(6): 778–784.

Kohima, N., Jawaharlal, M., Praneetha, S., Kashyap, Poonam and Somasundram, E. 2019. Genetic variability and character association studies in French bean (*Phaseolus vulgaris*) in Nilgiri hills of Tamil Nadu. *Indian Journal of Agricultural Sciences* **89**(12): 2,009–2,013.

Lal, R., 2017. Improving soil health and human protein nutrition by pulses-based cropping systems. *Advances in Agronomy* **145**: 167–204. http://dx.doi.org/10.1016/bs.agron.2017.05.003.

Panwar, A. S. and Munda, G.C.2007.Response of groundnut (*Arachis hypogaea* L.) to organic and inorganic sources of nutrient supply under mid hill altitude conditions. *Indian Journal of Agricultural Sciences* **77**(12): 814–818.

Panwar, A.S. 2006. Development of marshy land for crop production. (In) Proceedings of *National seminar on Land Resources Management for Sustainable Development*, held in Itanagar, Andhra Pradesh, 16–17 February, 2006 pp. 75–82.

Panwar, A.S., Babu Subhash, Noopur, K., Tahashildar, M., Kumar, Sanjeev, and Singh, A. 2019. Vertical cropping to enhance productivity and profitability of dry terraces in North Eastern Indian Himalayas. *Indian Journal of Agricultural Sciences* **89**(12): 2,020–2,024.

Panwar, A.S., Munda, G.C. and Hazarika, U.K. 2006. Response of sweet corn (*Zea mays*) to nitrogen, phosphorus and land configuration. *Indian Journal of Agricultural Sciences* **76**(5): 293–296.

Singh, R., Babu, Subhash, Avasthe, R.K., Meena, R.S., Yadav, G.S., Das, A., Mohapatra, K.P., Rathore, S.S., Kumar, A and Singh, C. 2021. Conservation tillage and organic nutrients management improve soil properties, productivity, and economics of the maize–vegetable pea system in the Eastern Himalayas. *Land Degradation and Development.* https://doi.org/10.1002/ldr.4066

Singh, R.P., Das, S.K., Bhaskar, Rao, V.M. and Narayana Reddy, M. 1990. Towards sustainable dry land agricultural practices. Central Research Institute for Dryland Agriculture, Hyderabad, Andhra Pradesh.

Yadav, G.S., Saha, P., Babu, Subhash, Das, A., Layek, J. and Debnath, C. 2018. Effect of no-till and raised-bed planting on soil moisture conservation and productivity of summer maize (*Zea mays*) in Eastern Himalayas. *Agricultural Research* **7(3)**: 300–310.