Sustainable diversification of maize (*Zea mays* L.) - legumes cropping systems for productivity, profitability and resource-use efficiency in West Garo Hills of Meghalaya, India

Mokidul Islam*, L.K. Nath¹ and T. Samajdar

ICAR Research Complex for NEH Region, Umroi Road, Umiam-793 103, Meghalaya, India.

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**ABSTRACT**

A field experiment was conducted at Instructional Farm of ICAR- Krishi Vigyan Kendra, Tura during *kharif*, *pre-rabi* and *rabi* season of 2011-12 to 2013-14 to determine the suitable production potential, profitability, resource use efficiency and sustainability of diversified maize-legumes cropping system. The five cropping sequences viz., $CS_1$: Maize + Blackgram (1:2) – green gram + maize (2:1) – tomato, $CS_2$: maize + green gram (1:2) – green gram + maize (2:1) – tomato, $CS_3$: maize + groundnut (1:2) – green gram + maize (2:1) – tomato, $CS_4$: maize + Soybean (1:2) – tomato and $CS_5$: maize sole – green gram – tomato were replicated four times using a randomized block design on sandy loam soil with low to medium fertility level and slightly acidic in reaction. The cropping system “Maize + Green gram(1:2) – green gram + maize (1:1) – tomato” was found to be most remunerative and sustainable with system productivity (175.49 q/ha), net return (Rs.3,38,725/ha), profitability (Rs. 928.01 /ha/day), benefit cost ratio (4.40), sustainable yield index (1.00), production efficiency (Rs.58.30/ha/day), relative economic efficiency (162.72%), except land use efficiency (LUE) which was the highest (85.75%) in “maize + groundnut (1:2) – green gram + maize (1:1) – tomato” cropping system. The lowest system productivity, net returns, profitability, production efficiency, land use efficiency etc was found in maize + soybean (1:2) - tomato followed by maize + groundnut - tomato and maize + green gram (1:1) – maize followed by maize - tomato cropping system. Hence, the cropping sequence maize + green gram(1:2) – green gram + maize (1:1) – tomato and maize + groundnut(1:2) – green gram + maize (1:1) – tomato were found to be the productive, profitable, remunerative, resource use efficient and sustainable in the mid hills sub-tropical regions of India.

**Key words:** Land use efficiency, Production efficiency, Sustainable diversification, system productivity.

**INTRODUCTION**

Modern agriculture has to ensure the future of food production while reducing the use of inputs, limiting environmental impacts and the loss of biodiversity. To stabilize crop production and to provide insurance mechanism against aberrant weather situations characterizing rainfed agriculture, intercropping could be a viable agronomic means of risk minimizing farmers’ profit and subsistence-oriented, energy-efficient and sustainable venture (Faroda et al. 2007). Since maize (*Zea mays* L.) is a widely spaced crop, inter-row space could profitably be utilized to inter crops legumes. Maize- legume intercropping system, besides increasing productivity and profitability also improves soil health, conserves soil moisture and increases total out turn (Padhi and Panigrahi 2006, Ummed et al. 2008). Spatial arrangement and plant population in an intercropping system have important effects on the balance of competition between component crops and their overall productivity.

Crop diversification has been recognized as an effective strategy for achieving the objectives of food security, nutrition security, income growth, poverty alleviation, employment generation, judicious use of land and water resources, sustainable agricultural development and environmental improvement (Hedge et al., 2003). The crop diversification may enhance profitability, reduce pests, spread out labour more uniformly, reduce risks from aberrant weather by different planting and harvesting times and source of high value products from new crops (Reddy and Suresh, 2009). In the era of shrinking resource base of land, water and energy, resource use efficiency is an important aspect for considering the suitability of a cropping system (Yadav, 2002). Hence, selection of component crops needs to be suitably planned to harvest the synergism among them towards efficient utilization of resource base and to increase overall productivity (Anderson, 2005). Monocropping is prevalent in mid hills of Meghalaya with low productivity, resource use and cropping intensity which could not bridge the gap between the production and requirement of food grains for the people of the state. Keeping these facts in view, the present investigation was carried out to determine most productive, resource use efficient and remunerative sustainable diversified maize -legumes cropping system.

*Corresponding author’s e-mail: mislam01d@yahoo.co.in
¹Krishi Vigyan Kendra, Lakhimpur, Assam Agricultural University, Assam-787 032, India.
under rainfed sub-tropical mid hills (above 330 m asl) in West Garo Hills district of Meghalaya.

MATERIALS AND METHODS

Study sites: A field experiment was conducted at Instructional Farm of ICAR-KVK Tura during kharif, pre-rabi and rabi season of 2011-12 to 2013-14 located at 25°29’45.3” N, 90°12’28.4” E and 330 meters above mean sea level on a well drained sandy loam soil under rainfed conditions. The climate was sub-tropical with average annual rainfall of 3305 mm, almost 97% of which is received from April to mid of October (Fig 1). A total of 4002.5, 3404 and 2766.6 mm rainfall in 129, 85 and 130 rainy days was received during the crop growing season in the respective years of 2011, 2012 and 2013, respectively. The soil of the experimental site was high organic carbon (0.98-2.65%), low to medium nitrogen (KMnO$_4$–N 263.07-288.16 kg/ha) and phosphorus (13.38 kg/ha Olsen P), medium in potash (216.3 kg/ha NH$_4$OAC-K) and acidic to slightly acidic in reaction (pH 4.05-5.51).

Experimental design and treatments: The treatments consisted of five cropping sequences viz., CS$_1$: maize one row plus Blackgram two rows followed by green gram two rows plus maize one row followed by tomato, CS$_2$: Maize one row plus green gram two rows followed by green gram two rows plus maize one row followed by tomato, CS$_3$: maize one row plus groundnut two rows followed by green gram two rows plus maize one row followed by tomato, CS$_4$: maize one row plus soybean two rows followed by tomato and CS$_5$: maize sole followed by Green gram followed by tomato were tested in a randomized block design replicated four times.

Field planting and management: ‘RCM 76’ maize, “Samrat” greengram, ‘Kalindi’ blackgram, “JS 335” soybean and “Megha tomato 3” tomato were sown on a well prepared field as per the treatment. First crop maize was sown at the spacing of 60 x 25 cm and intercrops Blackgram, greengram, groundnut, soybean were sown at 30x10 cm spacing on April and harvested in July. Second crop greengram and maize was sown by dibbling method in reverse order in rows as per treatments on August and harvested in November. The third crop tomato was sown in nursery on last week of October and transplanted in November which was harvested in three pickings upto first week of February. Mulching was used in tomato for soil and moisture conservation during the dry period of the season. Under monoculture cropping, maize crop received half nitrogen (30 kg N ha$^{-1}$ as urea) and full P (40 kg P$_2$O$_5$ ha$^{-1}$ as single superphosphate) and K (40 kg K$_2$O ha$^{-1}$) as basal and remaining half nitrogen (30 kg N ha$^{-1}$ as urea) was top-dressed at knee-height stage. However, entire dose of 20 kg N as urea and 20 kg P$_2$O$_5$ ha$^{-1}$ as single superphosphate was drilled basally in second crop greengram + maize intercropping system. In case of intercropping systems, the required amounts of fertilizers (N and P) were applied depending on the row arrangements of component crops. Recommended intercultural practices and plant protection measures were followed as and when required for successful cultivation of crops.

Data collection and analysis: Market prices prevailing during the crop season each year were used for computing maize equivalent yield. Economics of various cropping systems was also worked out to find out the most feasible and remunerative cropping system under rainfed conditions. Total field duration of a cropping system expressed in percentage of 365 days was taken as the land use efficiency, LUE (Tomar and Tiwari, 1990) of the system. Production efficiency was expressed as the ratio of system productivity in kg MEY/ha to total duration of the system in days (Patil et al., 1995). Sustainable yield index (SYI) was calculated as per Guggari and Kalaghatagi, (2004).

Sustainable yield index = \( Y - \delta \) / \( Y_{\text{Max}} \)

Where,

- \( Y \) = estimated mean yield
- \( \delta \) = estimated standard deviation
- \( Y_{\text{Max}} \) = observed maximum yield in the experiment over the years

Profitability of the system was calculated by dividing the net return per hectare in a sequence by 365 days. The production efficiency value was calculated by dividing the total grain production per hectare in a sequence with total duration of crops in a sequence (Tomar and Tiwari, 1990). The relative economic efficiency (REE) of the system was calculated and expressed in percentage.

Relative Economic Efficiency (REE) = \( \frac{B - A}{A} \times 100 \)

Where, A = Net return of existing system
B = Net return of diversified cropping system
RESULTS AND DISCUSSION

Productivity of component crops, system productivity and sustainable yield index (SYI): The highest maize equivalent yield was recorded in kharif maize + greengram (1:2) (April- July, 40.69 q/ha -1 MEY), pre-rabi green gram + maize (1:1) (Aug-Nov, 32.40 q/ha -1 MEY) and rabi tomato (Nov-Feb, 102.40 q/ha -1 MEY), system productivity (175.49 q/ha -1 year -1'), sustainable yield index (SYI -1.0) with treatment CS2: Maize + green gram(1:2) – green gram + maize (1:1) – tomato cropping system followed by CS3: maize + groundnut (1:2) – green gram + maize (1:1)– tomato(Table 1). This could be attributed to balanced competition and complementary effect of both crops for better utilization of available resources. Similar beneficial effects of legumes intercropping in relation to higher system productivity and profitability have also been reported by Birbal Sahu (2006) and Rao et al. (2009). The lowest total system productivity was recorded in CS4: maize + soybean(1:2) – tomato (115.27q/ha/year) followed by existing CS5: maize sole – green gram – tomato cropping sequence. The higher sustainable yield index (SYI) might be due to special advantage of legumes regarding stability of the system because of their legumes effect and wider adaptability to diverse conditions (Bastia et al, 2008). Similarly, Sheorani et al. (2010) reported that the highest production efficiency, sustainability yield index, income equivalent ration, net returns and B: C ratio was recorded with intercropping Blackgram with maize.

Resource-use efficiency: The maximum production efficiency (58.30 kg ha -1 day -1) was obtained in CS2: maize + green gram(1:2) – green gram + maize (1:1) – tomato cropping system with relative economic efficiency (137.69 %) except land use efficiency(LUE) which was highest (85.75%) in “maize + groundnut(1:2) – green gram + maize (1:1) – tomato” cropping system with greater combined yield. The higher production efficiency and relative economic efficiency might be due to higher system productivity as well as net return in the respective cropping system. Yadav et al. (2017) reported that conservation agriculture based crop management with legume diversified maize based rotations can be advocated as sustainable intensification strategy in north-western India and other similar agro-ecologies of South Asia. The lowest production efficiency was found in CS4: Maize + Soybean(1:2) – Tomato (36.95 kg ha -1 day -1) (Table-2) owing to lower grain yield due to its longer duration with less return of maize + soybean (1:2) in spite of higher market price in soybean sequence which had given relatively lower yield.

Profitability of cropping system: The cropping system “maize + green gram(1:2) – green gram + maize (1:1) – tomato” was found to be most remunerative and sustainable with higher net return (Rs.3,38,725 ha -1), profitability (Rs. 928.01 ha -1 day -1), benefit cost ratio (4.40) followed by “maize + groundnut(1:2) – green gram + maize (1:1) – tomato” cropping system followed by existing CS5: maize sole – green gram – tomato cropping sequence. The lower production efficiency and relative economic efficiency might be due to lower system productivity as well as net return in the respective cropping system.

Table 1: Productivity performance of different cropping system

<table>
<thead>
<tr>
<th>Cropping system</th>
<th>Kharif crop (Apr- July) (q/ha)</th>
<th>Pre-rabi crop (Aug-Nov) (q/ha)</th>
<th>Rabi crop (Nov-Feb) (q/ha)</th>
<th>System productivity (q/ha/year)</th>
<th>Sustainable Yield Index</th>
</tr>
</thead>
<tbody>
<tr>
<td>Main</td>
<td>Intercrop</td>
<td>Main</td>
<td>Intercrop</td>
<td>Tomato</td>
<td></td>
</tr>
<tr>
<td>CS1, maize + blackgram (1:2) – green gram + maize (1:1) – tomato</td>
<td>27.56</td>
<td>4.70 (9.40)</td>
<td>15.50</td>
<td>5.68 (11.36)</td>
<td>230 (92.0)</td>
</tr>
<tr>
<td>CS2, maize + green gram(1:2) – green gram + maize (1:1) – tomato</td>
<td>28.25</td>
<td>6.22 (12.44)</td>
<td>17.72</td>
<td>7.34 (14.68)</td>
<td>256 (102.4)</td>
</tr>
<tr>
<td>CS3, maize + groundnut(1:2) – green gram + maize (1:1) – tomato</td>
<td>27.67</td>
<td>8.27 (9.92)</td>
<td>16.89</td>
<td>7.23 (14.46)</td>
<td>244.78 (97.91)</td>
</tr>
<tr>
<td>CS4, maize + soybean(1:2) – tomato</td>
<td>25.30</td>
<td>1.50 (4.80)</td>
<td>-</td>
<td>-</td>
<td>212.92 (85.17)</td>
</tr>
<tr>
<td>CS5, maize Sole – green gram – tomato</td>
<td>26.22</td>
<td>-</td>
<td>7.69 (15.38)</td>
<td>-</td>
<td>222.0 (88.8)</td>
</tr>
<tr>
<td>CD (P=0.05)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>6.47</td>
</tr>
</tbody>
</table>

Data in parenthesis indicates the MEY (yield of intercrop x price of intercrop / price of main crop)
Table 2: Resource use efficiency of different cropping system

<table>
<thead>
<tr>
<th>Crop sequence</th>
<th>System productivity (q/ha/year)</th>
<th>Net return (Rs/ha)</th>
<th>Relative economic efficiency (%)</th>
<th>Production efficiency (kg/ha/day)</th>
<th>Land coverage (days)</th>
<th>Land-use efficiency (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CS₁: maize + blackgram (1:2) – green gram + maize (1:1) – tomato</td>
<td>155.82</td>
<td>289550</td>
<td>139.09</td>
<td>49.94</td>
<td>312</td>
<td>85.48</td>
</tr>
<tr>
<td>CS₂: maize + green gram (1:2) – green gram + Maize (1:1) – Tomato</td>
<td>175.49</td>
<td>338725</td>
<td>162.72</td>
<td>58.30</td>
<td>301</td>
<td>82.47</td>
</tr>
<tr>
<td>CS₃: maize + groundnut(1:2) – green gram + maize (1:1) – tomato</td>
<td>166.85</td>
<td>317125</td>
<td>152.34</td>
<td>53.31</td>
<td>313</td>
<td>85.75</td>
</tr>
<tr>
<td>CS₄: maize + soybean(1:2) – tomato</td>
<td>115.27</td>
<td>208170</td>
<td>-</td>
<td>36.95</td>
<td>303</td>
<td>83.01</td>
</tr>
<tr>
<td>CS₅: maize sole – green gram – tomato</td>
<td>130.40</td>
<td>246000</td>
<td>118.17</td>
<td>50.54</td>
<td>312</td>
<td>85.48</td>
</tr>
</tbody>
</table>

CD(P=0.05) 6.47

Table 3: Economic performance of different cropping system

<table>
<thead>
<tr>
<th>Cropping system</th>
<th>System productivity (q/ha/year)</th>
<th>Gross return (Rs/ha)</th>
<th>Net return (Rs/ha)</th>
<th>Profitability (Rs/ha/day)</th>
<th>B:C ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>CS₁: maize + blackgram (1:2) – green gram + maize (1:1) – tomato</td>
<td>155.82</td>
<td>389550</td>
<td>289550</td>
<td>793.29</td>
<td>3.90</td>
</tr>
<tr>
<td>CS₂: maize + green gram(1:2) – green gram + maize (1:1) – tomato</td>
<td>175.49</td>
<td>438725</td>
<td>338725</td>
<td>928.01</td>
<td>4.40</td>
</tr>
<tr>
<td>CS₃: maize + groundnut(1:2) – green gram + maize (1:1) – tomato</td>
<td>166.85</td>
<td>417125</td>
<td>317125</td>
<td>868.84</td>
<td>4.20</td>
</tr>
<tr>
<td>CS₄: maize + soybean(1:2) – tomato</td>
<td>115.27</td>
<td>288170</td>
<td>208170</td>
<td>570.33</td>
<td>3.60</td>
</tr>
<tr>
<td>CS₅: maize sole – green gram – tomato</td>
<td>130.40</td>
<td>326000</td>
<td>246000</td>
<td>673.97</td>
<td>4.01</td>
</tr>
</tbody>
</table>

CD(P=0.05) 6.47

Maize(Rs.2500/), Blackgram/greengram (Rs.5000/); Soybean (Rs.8000/q); Groundnut (Rs.3000/q), Tomato (Rs.1000/q);

Tomato" cropping system. The lowest system productivity, net return (Rs. 208170ha⁻¹), profitability(Rs 570.33ha⁻¹day⁻¹), and benefit cost ratio (3.60) was found in maize+ soybean (1:2)-tomato cropping system due to poor yield of soybean crop (Mukharjee D, 2010, Munda et al, 2005). Sharma et al. (2007) also reported that inclusion of vegetable crops in rice-based crop sequences improved the net return. Kumbhare et al. (2014) concluded that good agronomic management practices, awareness campaign of integrated pest management (IPM) and use of high yielding varities (HYV), pulses are more economic as compared to cereals.

CONCLUSION

The cropping sequence maize + green gram(1:2) – green gram + maize (1:1) – tomato" and maize + groundnut(1:2) – green gram + maize (1:1) – tomato were found to be the productive, profitable, remunerative, resource use efficient and sustainable in the mid hills sub-tropical regions of India.

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