Productivity and profitability of maize (Zea mays) as influenced by intercropping of rajmash (Phaseolus vulgaris) and nutrient management techniques under sub-alpine conditions of Jammu, India

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ABSTRACT
A field experiment was conducted during kharif 2011 and 2012 at Sartangal to study the effect of intercropping and nutrient management on productivity and profitability of cultivating maize under sub-alpine conditions of Jammu. The inter-cropping systems were sole maize, sole rajmash, maize + rajmash in a 1:1 row (1 rows of maize alternating with 1 row of rajmash) and maize + rajmash in 2:1 row (2 rows of maize alternating with 1 row of rajmash). The nutrient management treatments were, T₁ =control (no fertility), T₂ = 100% NPK (RDF, recommended dose of fertilizers), T₃ = 75% RDF + 25% N through farmyard manure (FYM) and T₄ =50% RDF + 50% N (FYM). Among cropping system maize + rajmash (1:1) produced highest maize grain equivalent yield (MEY, 7772 kg ha⁻¹), net returns (INR 52190 ha⁻¹), B:C ratio (1.81), land equivalent ratio (LER, 1.40) and area time equivalent ratio (ATER, 1.38). Whereas among nutrient management techniques, 75% RDF + 25% N (FYM) produced highest MEY (7681 kg ha⁻¹), net returns (INR 52585 ha⁻¹) and B:C ratio of 1.88 with highest LER (1.36) and ATER (1.33).

Key words: Aggressivity, Energetics, Intercropping, MEY, Relative crowding coefficient.

INTRODUCTION
Intercropping of cereals with legumes has been very popular in the rainfed areas (Dhima et al. 2007) due to its advantages for soil conservation (Anil et al. 1998), yield increment (Chen et al. 2004) and stability relative to sole cropping and fulfilling diversified needs of small farmers. It also helps in maintaining soil fertility (Patra and chatterjee, 1986), making efficient use of nutrients (Aggarwal et al. 1992, Nazir et al. 1997, Ahmad and Saeed 1998) and ensuring economic utilization of land, labour and capital (Morris and Garrity, 1993; Singh et al. 1996). The individual crops that make up an intercrop can differ in their use of resources spatially, temporally, or in form, resulting in overall more complementary and efficient use of resources than when they are grown in sole cropping. Different planting patterns or seeding ratios for cereal-legume intercropping have been practised by many researchers (Tsubo et al. 2001; Banik et al. 2006; Dhima et al. 2007). In Bhadarwah area legumes, such as rajmash, mung bean and black gram are used in intercropping with maize. However, intercropping of maize with rajmash is extensively used and common in Bhadarwah. Maize is characterised by aggressivity in cereal legume mixtures and improved the quantity of cropping system (Banik and Bagchi, 1996), while legumes are thought to improve the quality of its associated crops (Banik and Bagchi, 1996). However, unfortunately there is, at present, no proper and economically viable inter-cropping system in practice. The farmers sow maize with rajmash by just mixing the seed without any proportion and row arrangement. Thus, it is imperative to develop efficient system of maize + rajmash cultivation to increase productivity per unit area and time. The efficiency of native and applied nutrients may be increased by the combined use of organic and inorganic fertilisers. Organic manures not only act as the source of nutrients, but modify soil – physical behaviour and increase the efficiency of applied nutrients (Pandey et al. 2009). However it is imperative to use technologies in integrated manner so that the potential yield of maize intercropped with rajmash could be realized on sustained basis. Hence, the present investigation was undertaken to evaluate maize + rajmash intercropping and nutrient management techniques for higher sustained productivity of maize under sub-alpine conditions of Jammu.

MATERIALS AND METHODS
An experiment was conducted at Sartangal Farm located at 74° 34' and 76° 30’N, 32° 30' and 34° 15’E with altitude almost 1800m amsl during kharif 2011 and 2012. The soil of the experimental site was clay loam in texture, high in soil organic carbon (0.82%), low in available nitrogen (182 kg ha⁻¹), medium in available phosphorus (15.5 kg ha⁻¹) and high in available potassium (175 kg ha⁻¹). The experiment comprising of sixteen treatment combination of four cropping
systems viz., sole maize, sole rajmash, maize + rajmash in 1:1 (1 rows of maize alternating with 1 row of rajmash) and maize + rajmash in 2:1 (2 rows of maize alternating with 1 row of rajmash), and four nutrient management techniques viz., Tp = control, T1 = 100% NPK (RDF, recommended dose of fertilisers N:P2O5:K2O), T2 = 75% RDF + remaining 25% N through farmyard manure (FYM), T3 = 50% RDF + remaining 50% N through farmyard manure (FYM). Replicated thrice was conducted in split plot design. The cropping systems were taken in main plots and nutrient management techniques in sub-plots. The crops were sown on 29th April during both the years. Row spacing of 75 cm x 20 cm was followed for sowing of sole as well as intercropped maize. For maize as a sole crop, spacing of 60 cm x 20 cm was followed. The varieties sown were Kanchan 612 and local (chinta selection) for maize and rajmash, respectively. The seed rate of maize was 40 kg ha⁻¹ for each treatment. The seed rate of rajmash as sole crop was 30 kg ha⁻¹ whereas for intercropping it was calculated on the basis of number of rows. Before sowing the seeds of rajmash and maize were treated with baovis in @ 2g/kg of seed. In the sole crop, fertiliser dose was given as per respective crop’s recommendation. In intercropping it was that of main crop viz. maize. The recommended doses of N:P2O5:K2O for sole rajmash was 20:60:30 kg ha⁻¹. In rajmash, half dose of nitrogen and entire phosphorus and potassium was applied at the time of sowing. The remaining half nitrogen was top dressed at 30 days after sowing. In maize, recommended dose of N:P2O5:K2O was 60:40:20 kg ha⁻¹. The 2/3 of nitrogen and entire phosphorus and potassium was applied at the time of sowing through urea, diammonium-phosphate and muriate of potash. The remaining nitrogen was applied in two equal splits at knee high and tassel stages. The FYM as per treatment was applied 2 weeks before sowing. Weeds were controlled manually during both the years by giving two hand weedicings first at 25 days after sowing in both crops and second hand weeding at knee high stage in maize and after 55 days in sole rajmash. No irrigation was given to the crops as the crop is rainfed. Harvesting was done at 158-163 days and 149-152 days after sowing for maize and rajmash, respectively during 2011 and 160-164 days and 151-154 days, respectively, during 2012. The maize was shelled by hand and the yield was expressed at 14% moisture content. Rajmash were harvested manually. The total productivity of the cropping system was expressed as maize equivalent yield.

Land equivalent ratio (LER) was computed by using the formula described by Willey et al (1980) as below:

$$LER = \frac{Yab}{Yba} + \frac{Ybb}{Yaa}$$

Where

La and Lb are the LERs for the individual crops of the system

Yab = Intercrop yield of crop ‘a’

Yba = Intercrop yield of crop ‘b’

Yaa = Pure stand yield of crop ‘a’

Ybb = Pure stand crop yield of ‘b’

When the value of LER is greater than 1, the intercropping favours the growth and yield of the species where as when LER is lower than 1, the intercropping negatively affects the growth and yield of crops grown in mixtures (Caballero et al. 1995).

Area time equivalent ratio (ATER) was determined by the formula proposed by Hiebsch and Mc Collum (1987) as follows:

$$ATER = \frac{(Ryc x tc) + (Ryp x tp)}{T}$$

Where

Ryc = Relative yield of crop c (main crop)

Ryp = Relative yield of crop p (intercrop)

tc = Growth duration (days) for crop ‘c’

tp = Growth duration (days) for crop ‘p’

T = Growth duration (days) for the whole system

The competitive ratio was calculated by the formula proposed by Willey et al (1980):$

$$CRa = \frac{Yab}{Yaa - Yab} - \frac{Zab}{Zba}$$

Where

Yab = Intercrop yield of crop ‘a’

Yaa = Pure stand yield of crop ‘a’

Zba and Zab are sown proportions of crop ‘a’ and ‘b’ in an intercropping system

The aggressivity (A) was calculated by the following formula proposed by McGilchrist (1965):

$$Aab = \frac{Yab}{Yaa x Zab} - \frac{Yba}{Ybb x Zba}$$

The competitive ratio was calculated by the following formula as proposed by Willey et al (1980):

$$CRa = \frac{Yab}{Yaa x Zab} \div \frac{Yba}{Ybb x Zba}$$

RESULTS AND DISCUSSION

Growth and yield attributes: Plant height (2.72 cm), cob diameter (16.13 cm), and number of grains/cobs (360.25) of maize were significantly higher in its sole crop followed by maize + rajmash inter-cropping in a 2:1 row ratio (Table 1). It might be due to inter specific competition for growth resources viz., light, moisture and nutrients arising due to increased population pressure per unit land area or demand exceeding supply or due to both. Chui (1988) observed that dry matter yields at maturity in intercrops was reduced by 24.4 per cent and 11.6 per cent when maize and French bean were grown in same row and French bean between two maize
Table 1: Effect of cropping system and nutrient management technique on yield attributes and yield of maize in maize + rajmash cropping system (average of two years)

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Plant height (cm)</th>
<th>Cobs/plant</th>
<th>Cob diameter (cm)</th>
<th>Grains/cob</th>
<th>Grain yield (kg ha(^{-1}))</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2011</td>
<td>2012</td>
<td>Mean</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cropping system</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sole maize</td>
<td>2.72</td>
<td>1.14</td>
<td>16.13</td>
<td>360.25</td>
<td>4533</td>
</tr>
<tr>
<td>Sole rajmash</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Maize + rajmash (1:1)</td>
<td>2.60</td>
<td>1.10</td>
<td>15.34</td>
<td>276.63</td>
<td>4038</td>
</tr>
<tr>
<td>Maize + rajmash (2:1)</td>
<td>2.62</td>
<td>1.11</td>
<td>16.06</td>
<td>326.14</td>
<td>4286</td>
</tr>
<tr>
<td>SE (m±)</td>
<td>0.04</td>
<td>0.04</td>
<td>0.21</td>
<td>10.71</td>
<td>69</td>
</tr>
<tr>
<td>C.D (0.05)</td>
<td>0.13</td>
<td>N.S</td>
<td>0.62</td>
<td>31.41</td>
<td>201</td>
</tr>
<tr>
<td>Fertility Management</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Control</td>
<td>2.48</td>
<td>1.00</td>
<td>14.81</td>
<td>245.89</td>
<td>3545</td>
</tr>
<tr>
<td>100% RDF</td>
<td>2.69</td>
<td>1.20</td>
<td>15.74</td>
<td>367.56</td>
<td>4710</td>
</tr>
<tr>
<td>75% RDF + 25% FYM</td>
<td>2.79</td>
<td>1.15</td>
<td>16.23</td>
<td>372.61</td>
<td>4637</td>
</tr>
<tr>
<td>50% RDF + 50% FYM</td>
<td>2.62</td>
<td>1.09</td>
<td>16.09</td>
<td>297.99</td>
<td>4250</td>
</tr>
<tr>
<td>SE (m±)</td>
<td>0.07</td>
<td>0.05</td>
<td>0.28</td>
<td>12.36</td>
<td>79</td>
</tr>
<tr>
<td>C.D (0.05)</td>
<td>0.14</td>
<td>0.14</td>
<td>0.84</td>
<td>36.26</td>
<td>232</td>
</tr>
</tbody>
</table>

Nutrient management techniques also influenced the yield attributes of maize crop. Highest maize plant height (2.79 cm), cob diameter (16.23 cm), and no. of grains/cob (372.61) were recorded under integrated nutrient management where 75% NPK was supplied through fertilizers and 25% N through FYM (Table.1). Similar results were reported by Rao et al. 2010. However it was comparable with 100% RDF. Maximum number of cobs/plant (17.15) were found in its sole crop (Table.2). Salomon (1990) concluded that number of pods per plant decreased with increase in maize and French bean population per hectare. Ganajaxi (2008) also reported that sole vegetable French bean had higher number of pods per plant than other French bean based cropping systems (6.6-11.63). However, grains/pod were highest (5.36) in maize + rajmash at 2:1 row ratio. The highest yield attributes in rajmash under sole rajmash crop and wider rows of 2:1 might be due lower competition and reduced shading effect of maize crop over rajmash. Singh et al., (2009) also showed the similar results.

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Grain/seed yield: Average grain yield of maize was significantly higher (4434 kg ha\(^{-1}\)) in sole maize followed by maize + rajmash (2:1) (4157 kg ha\(^{-1}\)) and maize + rajmash (1:1) (3905 kg ha\(^{-1}\)) intercropping (Table 1). Higher yield of sole maize over intercropped maize + rajmash was due to increased values of growth parameters i.e. number of cobs/plant, cob diameter and number of grains/cob in sole maize crop. This results showed that the pure stand of crops maintained supremacy over the intercropping system with rows, respectively, over sole maize. Similarly significantly highest number of pods/plant (17.15) of rajmash were found in its sole crop (Table.2). Salomon (1990) concluded that number of pods per plant decreased with increase in maize and French bean population per hectare. Ganajaxi (2008) also reported that sole vegetable French bean had higher number of pods (12.92) than other French bean based cropping systems (6.6-11.63). However, grains/pod were highest (5.36) in maize + rajmash at 2:1 row ratio. The highest yield attributes in rajmash under sole rajmash crop and wider rows of 2:1 might be due lower competition and reduced shading effect of maize crop over rajmash. Singh et al., (2009) also showed the similar results.
respect to economic yield, which might be due to limited disturbance of the habitat and interactional competition in the sole cropping environment (Aynehband and Behrooz, 2011 and Takim, 2012). Average highest seed yield (720 kg ha\(^{-1}\)) of rajmash was found where rajmash was grown as sole crop. It might be due to higher plant population when rajmash was sown as a sole crop. Similar results were also reported by Charak et al. (2012).

Adequate nutrient management treatments in sole as well as intercropped maize either with inorganic sources and organic sources or their combined use significantly enhanced grain yield of maize compared to control (Table 1). Highest yield (4710 kg ha\(^{-1}\)) was obtained with 100% RDF during the first year. During the second year and average maize grain yield was highest under 75% RDF + 25% N through FYM (4528 kg ha\(^{-1}\) and 4583 kg ha\(^{-1}\), respectively). The treatment 75% RDF + 25% N through FYM increased maize grain yield by 34.91% over control. The better effect of combined use of fertilizers and FYM might be due to increased growth and yield attributes. These results corroborated the findings of Tetarwal et al (2011). The interaction effect of treatments on yield was found statistically non-significant. Similarly, the highest seed yield of rajmash was recorded where 75% RDF + 25% N through FYM was applied (Table 2). Ghosh et al. 2006 also showed that integrated nutrient management (100% NPK + 4t FYM/ha) gave higher yield under soybean/pigeonpea intercropping system than 100% NPK and control. Maize equivalent yield (MEY) is the best tool to determine the overall productivity potential of an intercropping system. The data presented in Table 3 clearly showed that MEY was significantly higher in maize + rajmash (1:1) (7772 kg ha\(^{-1}\)) followed by maize + rajmash (2:1) (6610 kg ha\(^{-1}\)), sole rajmash (5826 kg ha\(^{-1}\)) and sole maize (5229 kg ha\(^{-1}\)). Singh et al. (2009) reported that sowing of lentil with oats is a profitable intercropping combination for temperate Kashmir. Further in case of nutrient management techniques the highest MEY (7681 kg ha\(^{-1}\)) was found where 75% RDF was coupled with 25% N through FYM. It might be due to adequate quantities and balanced proportions of plant nutrients supplied to the crop as per need during the growth period resulting in favourable increase in yield attributes which ultimately led towards an increase in economic yield. Improved physiochemical properties of soil through the application of organic manure might be the other possible reason for higher productivity (Pandey et al, 2009).

**Economics and energetics:** Highest average net returns of INR 52190 ha\(^{-1}\) and B:C ratio of 1.81 was accrued in 1:1 maize + rajmash followed by 2:1 maize + rajmash with net returns of INR 42287 ha\(^{-1}\) and B:C ratio of 1.57 (Table 3). Higher output prices of rajmash and higher maize yield had turned out to higher net returns and B:C ratio. Jabbar et al. (2009) also recorded higher net returns in an intercropping
system. Average energy output/input (22.14) and energy productivity (1.51 kg MJ⁻¹) was highest in sole rajmash (Table 3). Whereas highest specific energy of 1.07 MJ kg⁻¹ was obtained in sole maize.

Among nutrient management techniques 75% RDF coupled with 25% N through FYM fetched higher net returns of INR 52585 ha⁻¹ and B:C ratio of 1.88. These results are in close conformity with the findings of Tetarwal et al. (2011). Highest output/input and energy productivity of 26.69 and 1.82 kg MJ⁻¹, respectively, were found in control, which implies that energy output in terms of yield was compensated by energy input through manures and fertilizers. Similar results were reported by Ghosh et al. (2006). However, higher specific energy of 0.99 MJ kg⁻¹ was recorded where 100% RDF was applied.

**Yield advantage and competitive functions:** Land Equivalent ratio (LER) (Table 4) was higher (1.40) in maize + rajmash (1:1), indicating that 40% more area would be required for producing same quantity of grain yield for solitary cropping system compared to intercropping. Similar results were found by Yilmaz et al., (2008). Land equivalent ratio does not take into account the time for which land is occupied by the component crops of an intercropping system, area time equivalent ratio (ATER) was calculated. It was revealed that Area time equivalent ratio in all the intercropping systems was smaller than land equivalent ratio indicating the over estimation of resource utilisation in the later. Area time equivalent ratio exhibited an average value of 1-38% in intercropping systems compared to sole crops of maize and rajmash. The highest ATER value of 1.38 was recorded for maize + rajmash (1:1) followed by 1.21 for maize + rajmash (2:1). The relative crowding coefficient of maize was much higher than 1 as in maize + rajmash (2:1), the value was 17.33 indicating an absolute yield advantage of maize over rajmash. This result showed that maize was more competitive than rajmash. These findings were corroborated with Aynehband and Behrooz (2011). In all cropping systems the aggressivity value was positive. It showed that maize was the dominant species. Further highest competitive ratio of maize (1.36) is found under maize + rajmash (1:1) and that of rajmash under maize + rajmash (2:1) (0.76). Such a result was expected since cereals are more competitive than legumes. Similar results were found by Yilmaz et al. (2008).

Among nutrient management techniques highest LER and ATER of 1.36 and 1.33, respectively, was recorded where 75% RDF and 25% FYM was applied followed by 50% RDF and 50% FYM with 1.32 and 1.30, respectively. Whereas, highest relative crowding coefficient was found in 100% RDF (12.70). Further highest competitive ratio of maize (1.44) is found under control and that of rajmash (0.81) under INM treatments, where 75% RDF and 25% FYM was applied.

**CONCLUSION**

From the results it can be concluded that sowing of maize + rajmash (1:1) with 75% NPK through fertilizers and 25% N through FYM may be a productive and profitable venture for sub-alpine Jammu regions.

**REFERENCES**


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**Table 4: Effect of cropping system and nutrient management technique on LER, ATER, aggressivity, competitive ratio and relative crowding coefficient of maize and rajmash in maize + rajmash cropping system (average of two years)**

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Land Equivalent ratio</th>
<th>Area Time Equivalent Ratio</th>
<th>Aggressivity</th>
<th>Competitive ratio</th>
<th>Relative Crowding Coefficient</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Cropping system</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sole maize</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Sole rajmash</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Maize+ rajmash (1:1)</td>
<td>1.40</td>
<td>1.38</td>
<td>0.0023</td>
<td>1.36 (0.75)</td>
<td>6.90</td>
</tr>
<tr>
<td>Maize+ rajmash (2:1)</td>
<td>1.23</td>
<td>1.21</td>
<td>0.0024</td>
<td>1.33 (0.76)</td>
<td>17.33</td>
</tr>
<tr>
<td><strong>Fertility management</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Control</td>
<td>1.30</td>
<td>1.28</td>
<td>0.0028</td>
<td>1.44 (0.71)</td>
<td>12.50</td>
</tr>
<tr>
<td>100% RDF</td>
<td>1.30</td>
<td>1.28</td>
<td>0.0028</td>
<td>1.43 (0.71)</td>
<td>12.70</td>
</tr>
<tr>
<td>75% RDF + 25% FYM</td>
<td>1.36</td>
<td>1.33</td>
<td>0.0018</td>
<td>1.25 (0.81)</td>
<td>11.04</td>
</tr>
<tr>
<td>50% RDF + 50% FYM</td>
<td>1.32</td>
<td>1.30</td>
<td>0.0020</td>
<td>1.28 (0.76)</td>
<td>9.72</td>
</tr>
</tbody>
</table>


