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Role of Intercropping on Production and Land Use Efficiency in the Central Himalaya, India

Abhishek Chandra[1*], L.S.Kandari[2], Vikram S. Negi[3], R.K. Maikhuri[3] and K.S. Rao[1]

[1]Department of Botany, University of Delhi, New Delhi 110 007, India
[2]School of Natural Resource Management and Environmental Sciences, College of Agriculture and Environmental Sciences, Haramaya University, P.O. Box # 337, Dire Dawa, Ethiopia
[3]G.B.Pant Institute of Himalayan Environment and Development,
Garhwal Unit, Srinagar (Uttarakhand) 246 174, India
*E-mail: ac.india@gmail.com

Abstract

Finger millet (*Eleusine coracana* (L.) Gaertn.) and black gram (*Vigna mungo* (L.) Hepper) are the most important staple food crops among food habitats of central Himalaya, India. Intercropping is common, which allows for better resource use efficiency as compared to monocropping. The different times of sowing and harvesting as well as different demands on environmental resources extends the duration of resource use and management. Finger millet is known for its high mineral contents, and legumes for the protein contents. Legumes fix nitrogen symbiotically if effective strains of rhizobium are present in the soil that improves the fertility status and thereby nutrient utilization. Such complementarity between crops in resource use is important in low input subsistence farming systems. The present study compared the productivity of finger millet/black gram intercropping with sole cropping and examined the competitive interactions of finger millet and black gram in intercrops. Net production in mixed cropping systems was economically higher by controlling diseases and intercropping yielded the maximum land equivalent ratios and the highest replacement value. At medium intensity cropping, this system is recommended for land-constrained poor farmers to reduce the utilization of external inputs such as fertilizer and pesticides. The result of this study showed that intercropping of finger millet with black gram at a density not exceeding 75% of a sole black gram culture may improve overall yields and income from mountain agriculture system.

Keywords: Cropping System; Productivity; Yield stability; Land equiventant ratio; System Productivity Index, Black gram; Finger millet

Introduction

Intercropping is a common practice, not only in the central Himalaya, India but worldwide because it minimizes the risk of crop failure due to adverse effects of pests, improves the use of limited resources, reduces soil erosion, increases yield stability and is cost effective. (Maikhuri *et al*., 1996; Jensen, 1996; Anil *et al*., 1998; Dapaah *et al*., 2003; Chandra, 2007; Chandra *et al.,* 2009a). Crops and cropping systems in the central Himalayas are diverse due to large agro-ecological and cultural diversity, which has led to variable cropping patterns. About 80% of people in the Garhwal hills of the central Himalayas practice subsistence agriculture (Maikhuri et al. 2001). Land holdings are small, with fragmented and terraced slopes covering 85% of total agricultural land which is rainfed; while the valley area, which covers 15% of agricultural land, is irrigated. In the central Himalayas, intercrop combinations traditionally involve cereals with millet, millet with legumes, and legumes with legumes. However, the continuous diffusion of modern varieties has changed the landscape from on-farm crop genetic diversity to increasingly planting genetically uniform varieties (Saxena *et al*., 2005, Chandra *et al.,* 2009b, 2010a; 2010b). Growing non-leguminous crops with legumes provide climbing support to the later, reduces disease attack, facilitates weed management and reduces the harmful impacts of continuous and intensive cereal cultivation on soil fertility.

With the growing population pressure and the need to produce diverse products from ever shrinking land holdings, farmers in the central Himalayas have been involved in intercropping legumes, such as finger millet mixed with black gram or other legumes. Intercropping a legume with a non-legume would be more valuable because of the advantage to the non-legumes from nitrogen fixed by the legumes. Furthermore, two crops differing in height, canopy, adaptation and growth habits grow simultaneously with least competition (Keerio and Aslam, 1986; Bhatti *et al*., 2006); greater yield stability over different seasons; better use of land resources; possibility of better control of weeds; pests and diseases (Benites *et al*., 1993; Jensen, 1996; Chu *et al*., 2004). Intercropping finger millet (non-legume) with legumes often results in higher resource use efficiency compared to sole cropping (Maikhuri *et al*., 1996; 1997; Chandra 2007). The intercropping species that differ in sowing and harvesting times, and their maximum demands on environmental resources, extends the duration of resource use (Maikhuri et al 1997; Chandra et al 2011a, 2011b). Finger millet (*Eleusine coracana*) is known for its high mineral contents (Gopalan *et al*., 2004; Chethan and Malleshi, 2007) and legumes fix nitrogen symbiotically if effective strains of rhizobium are present in the soil. Such complementarity between crops in resource use is particularly important in low input subsistence farming systems such as those in the central Himalayas. Finger millet and black gram are commonly intercropped and these species are the most important staple food crops in the Garhwal area of the central Himalaya.

The rainfed agricultural land is managed in almost two equal halves by the villages namely 'Mullasar' and 'Mallasar' that are situated either side of it i.e. below and above it, respectively. Traditionally, one half is put to fallow during winter, resulting in four cropping seasons every two years. A cropping sequence is presumed to start after the winter fallow: first kharif season (first crop season), first rabi season (second crop season), second kharif season (third crop season) and second rabi season (fourth crop season). During the third crop season, plots are cropped with finger millet, black gram and soybean as sole crops, finger millet was sown with black gram or one of seven legumes (black gram, green gram, adjuki bean, cow pea, horse gram, black soybean, white soybean), or a mixture of seven legumes. The yearly average kharif season area covered by finger millet and black gram is about 40% of the total cultivated area (Maikhuri *et al*., 1997; 1999, Chandra, 2007; Chandra *et al.*, 2009a; 2010a; 2010b 2011a; 2011b).

The aim of the present study was to assess the agronomic feasibility of traditional finger millet/black gram intercropping as a means of sustainable intensification of farming systems in the central Himalayas. The specific objectives were to compare the productivity of finger millet/black gram intercropping with sole cropping and to examine the competitive interactions of finger millet and black gram as intercrops.

Materials and Methods

The experiment was conducted in year the 2004 and 2005 kharif cropping (May to September) seasons in farmers' fields (30° 17.368' N, 77° 16.868' E, and 912 m above sea level) in Langasu, Uttarakhand in the central Himalayas. Annual rainfall was 1055 mm and average minimum and maximum air temperatures were 10°C and 35°C, respectively. Average soil temperature was varying from 7°C to 22°C. Humidity was leying though out the year between 50-65% (Figure 1). Soil parent material was represented by feldspathic quartz schist, quartz muscovite schist and chlorite schist, and classified as dystric cambisol (Semwal *et al*., 2002). Soil physical and chemical properties of the trial fields are in table 1.

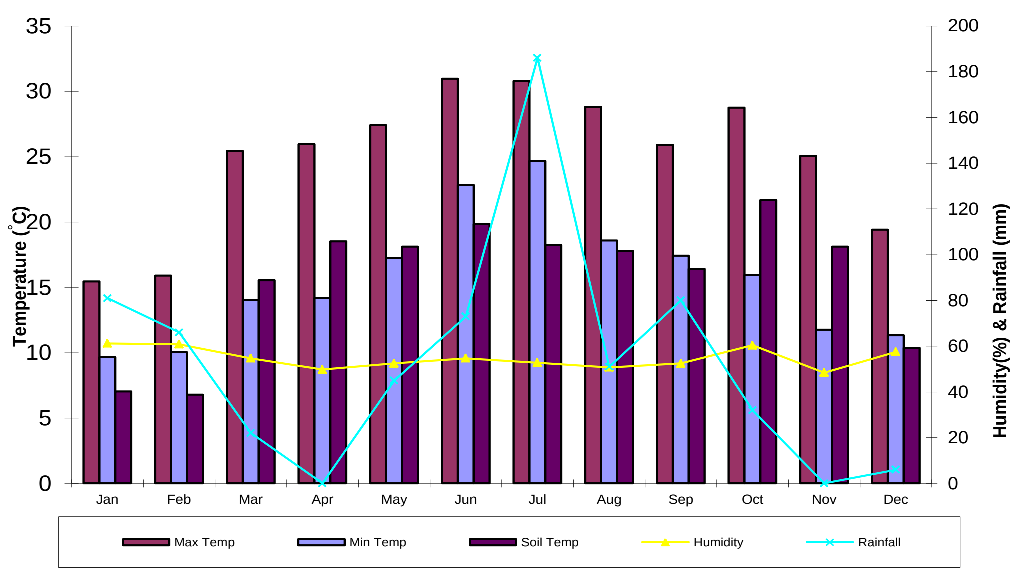

Figure 1 Climatic data of village Langasu, Uttarakhand India

Table 1 Physical and chemical properties of fine clay loam soil from the upper surface

Property	Value
Soil texture (%)	
Sand	15.4
Silt	28.6
Clay	56.1
pH	6.80
Organic carbon (%)	1.033
N (%)	0.727
P (%)	0.149
Na (%)	0.063
K (%)	0.191
Ca (%)	0.095
Mg (%)	0.096

There were nine treatments: black gram (25 kg ha^{-1}) intercropped with finger millet at seed rates of 25, 50 or 75% of the sole finger millet seed rate (30 kg ha^{-1}), and finger millet (30 kg ha^{-1}) intercropped with black gram at seed rates of 25, 50 or 75% of the sole black gram seed rate (25 kg ha^{-1}), sole cultures of black gram (25 kg ha^{-1}), sole cultures of finger millet (30 kg ha^{-1}) and 100% of sole black gram (25 kg ha^{-1}) with 100% of finger millet (30 kg ha^{-1}). Seeding rate of sole cultures of black gram and finger millet were 25 and 30 kg ha^{-1} respectively (Table 2).

Table 2 Details of treatments for intercropping finger millet and black gram

Treatments	Details
T1	Sole FM
T2	Sole BG
T3	FM/BG (100:25)
T4	FM/BG (100:50)
T5	FM/BG (100:75)
T6	FM/BG (100:100)
T7	FM/BG (25:100)
T8	FM/BG (50:100)
T9	FM/BG (75:100)

Traditional landraces of finger millet and black gram were used for the experiment. The design was a randomized complete block with four replications. A plot size of 1 m × 1 m was used. Fertilizers, farm yard manure (FYM) and pesticide were not used during the experiments.

Finger millet equivalent yield of the total economic yield of crop. The equivalent yield was calculated using formula:

$$\frac{\text{Economic yield of black gram (t/ha)} \times \text{monetary value of black gram (Rs/ha)}}{\text{Monetary value of finger millet (Rs/ha)}}$$

Land equivalent ratio (LER) LER compares yields from growing two or more crops together with yields from growing the same crop in monocultures or pure stands. LER was calculated as:

$$LER = \frac{Yij}{Yii} + \frac{Yji}{Yjj}$$

where Yii and Yjj denote yield of crops i and j in sole cropping and Yij and Yji the corresponding yield in intercropping. An LER of 1.0 indicates that intercropping and sole cropping have yield equivalence. LER >1.0 indicates that intercropping has a yield advantage over sole cropping while an LER <1.0 indicates a disadvantage of intercropping.

System productivity index (SPI) was calculated based on Ode (1991)

$$SPI = \frac{Sa}{Sb} Yb + Ya$$

where Sa and Sb yield of primary and secondary crop in sole cropping and Ya and Yb are yield of primary and secondary crop in intercropping.

Intercrops of each treatment were harvested separately. Seed yield, yield components, above ground biomass, plant height, crop lodging and weed biomass were recorded carefully.

Results and Discussion

The significant ($p \leq 0.001$) differences occurred between treatments for grain yield of finger millet and black gram (Table 3). The yield of each sole crop was greater than the respective intercropping yields. As the black gram seeding proportion increased from 25% to 75% with 100% seeding of finger millet, seed yield of black gram increased from 21% to 72%; but seed yield of finger millet decreased from 92% to 60% of the respective sole crop yields. Intercropping black gram with finger millet resulted in more total grain yield and finger millet yield equivalents compared to sole crops. On the basis of seeding percentages in the mixtures, all intercropping treatments had relatively more yield of black gram than expected (Table 3). However, the proportion of straw in the intercropping plants was less than that of finger millet alone. As the proportion of black gram in the mixture increased from 25% to 75%, straw yield of finger millet decreased from 94% to 71% and black gram increased from 15% to 66% of the respective sole crop straw yields.

Seed yields of black gram were similar in both years. Year by treatment interaction effects were not significant for grain yields of the component crops. Differences between treatments were highly significant ($p \leq 0.001$) for partial and total LERs. Partial LERs in intercrops ranged from 0.60 to 0.92 for finger millet and 0.21 to 0.72 for black gram, and total LERs ranged from 1.13 to 1.32 (Table 3). The highest value (1.32) was from the binary combination of 100:75 finger millet: black gram (Table 3). The growing season significantly ($p \leq 0.01$) influenced partial LERs of finger millet. Year by treatment interaction effects were not significant for partial or total LERs, implying that sole and intercrops responded similarly to treatments over the two growing seasons.

Table 3 Effect of intercropping on grain yields of finger millet (FM) and black gram (BG) (kg ha^{-1}), finger millets equivalents (kg ha^{-1}) and land equivalent ratio (LER) and SPI in 2004 and 2005

Factor	**Grain yield**		**Finger millet equivalent**	**LER values**	**SPI**	
	FM	**BG**			**FM**	**BG**
2004	2440	1840	9800	1.95	4766.22	3770.00
2005	2850	1930	10570	2.17	5290.00	4184.30
Inter proportion (%)						
Sole FM	2440		2440	1.00	2440.00	1930.00
Sole BG		1930	7720	1.00	2440.00	1930.00
FM/BG (100:25)	2350	450	4150	1.20	2918.91	2308.81
FM/BG (100:50)	2210	650	4810	1.24	3031.76	2398.07
FM/BG (100:75)	2040	850	5440	1.28	3114.61	2463.61
FM/BG (100:100)	1600	1050	5800	1.20	2927.46	2315.57
FM/BG (25:100)	1200	1250	6200	1.14	2780.31	2199.18
FM/BG (50:100)	1500	1600	7900	1.44	3522.80	2786.48
FM/BG (75:100)	1700	1800	8900	1.63	3975.65	3144.67

System Productivity Index (SPI) was always greater in finger millet (primary crop) than black gram (secondary crop). The value of total yield, LER and SPI were also highest in the 75:100 FM:BG treatment and lowest in the sole crops. Weed biomass was highest in sole finger millet plots (250 kg/ha) Table 4 The panicle size of finger millet, and the number of pods per plant, seeds per pod, seed weight and nodule number of black gram were not affected by intercropping treatments. Grain and biomass yield of finger millet was significantly ($p \leq 0.01$) greater in 2005 than in 2004 (Table 4).

Although seed yields of component crops were low as compared to their respective sole crop but total land productivity improved in intercrops, which is supported by total LER values. Similar results have been reported for intercrops of wheat and field bean (Bulson *et al*., 1997; Haymes and Lee, 1999; Hauggaard-Neilsen and Jensen, 2001) and field pea and barley (Jensen, 1996). Despite this, total straw productions of finger millet in intercrops were less than sole finger millet. Since finger millet straw is the preferred crop residue used as livestock feed, the implication of this in terms of total economic return and its impact on adoption of finger millet/black gram intercropping in the central Himalayas needs to be assessed further.

Table 4 Effect of intercropping on agronomic traits and weed biomass of finger millet (FM) and black gram (BG) in intercrops and sole culture (Mean ± standard deviation, n = 3)

Inter Proportion	**Total biomass (kg ha^{-1})**		**Grain biomass (kg ha^{-1})**		**Weed biomass (kg ha^{-1})**
	FM	**BG**	**FM**	**BG**	
Sole FM	4800 ± 50		2440± 36		250± 25
Sole BG		5140± 36		1930± 30	150± 10
FM/BG (100:25)	4500 ± 66	1250± 26	2350± 50	450± 25	150± 10
FM/BG (100:50)	4400 ± 43	2500± 65	2210± 50	650± 30	125± 13
FM/BG (100:75)	4200 ± 50	3000± 43	2040± 40	850± 10	100± 10
FM/BG (100:100)	4000 ± 66	3800± 55	1600± 25	1050± 25	50± 15
FM/BG (25:100)	1200 ± 68	4800± 26	1200± 45	1250± 25	105± 5
FM/BG (50:100)	2500 ± 55	3800± 26	1500± 43	1600± 40	90± 5
FM/BG (75:100)	3300 ± 78	3400± 60	1700± 26	1800± 50	75± 10

Intercropping with legumes has a positive impact on symbiosis for nitrogen fixation and increasing soil fertility. The infertile land requires more nitrogen for proper plant growth and better yield and thus the demand for soil nitrogen in Himalayan rainfed agriculture is increasing day-by-day. Unique characteristics like high protein content (2-3 times more than cereals), nitrogen fixing ability, soil ameliorative properties and ability to thrive better under unfavorable conditions make pulses an integral component of agriculture and cuisine in central Himalaya. Intercropping black gram in finger millet reduced weed biomass to below that observed in sole finger millet, which agrees with the findings of Bulson *et al*. (1997) for wheat/field bean intercropping. On average, grain yields were lower in 2004 than 2005 for finger millet but not for black gram, possibly due to differences in flowering times of the two crops. Later flowering for finger millet means more exposure to late season moisture stress during the critical time of grain filling, particularly during the drier months of September and October in 2004.

Further increases in black gram density are likely to result in low finger millet yield than expected, implying further domination of finger millet by black gram. In the future it may be important to evaluate intercropping black gram at the full seeding rate of finger millet. A prime objective of contemporary intercropping studies is to assess the nitrogen economy of component crops. Future studies should assess the extent of nitrogen capture accruing from intercropping.

Conclusion

The study disclosed immense potential of Himalayan cultivated legume crops in mix farming system, which is an eco-friendly and beneficial approach to arrest the decline in soil fertility and yield of other crops. A finger millet/black gram intercropping system could be economically and environmentally advantageous under rainfed conditions in the central Himalaya, a region characterized by high population density, small farm size and low farm income. The complementary use of nutrient and water sources by the intercrop components and the need for reduced external inputs resulting from cereal/pulse intercropping are favourable, calling for further attention from research and development stakeholders in the central Himalayas. Based on the findings in this study, we propose that intercropping black gram with full finger millet at a density not exceeding 75% black gram may improve overall yields and incomes.

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References

Anil, L., Park, J., Phipps, R.H., Miller, F.A. 1998. Temperate intercropping of cereals for forage: a review of the potential for growth and utilization with particular reference to the UK. *Grass and Forage Science*, 53, 301–317.

Benites, J.R., McCollum, R.E., Naderman, G.C. 1993. Production efficiency of intercrops relative to sequentially planted sole crops in a humid tropical environment. *Field Crops Research*. 31, 1–18.

Bhatti, I.H., Ahmad, R., Jabbar, A., Nazir, M.S., Mahmood, T. 2006. Competitive behaviour of component crops in different sesame-legume intercropping systems. *Internation Journal of Agriculture and Biology*, 08 (2), 165–167.

Bulson, H.A.J., Snaydon, R.W., Stopes, C.E. 1997. Effects of plant density on intercropped wheat and field beans in an organic farming system. *The Journal of Agricultural Science Cambridge* 128, 59–71.

Chandra, A. 2007. Traditional agrodiversity management in central Himalayan village ecosystem. Ph.D. Thesis, University of Delhi, Delhi, India.

Chandra, A., Kandari, L. S., Payal K.C., Maikhuri, R.K. Rao, K.S., Saxena, K.G., 2010b. Conservation and Sustainable Management of Traditional Ecosystems in Garhwal Himalaya, India, *New York Science Journal*, 3(2), 71-77

Chandra, A., Pardha Saradhi, P., Maikhuri, R.K., Saxena, K.G., Rao, K.S. 2011b. Traditional Agrodiversity Management: A Case Study of Central Himalayan Village Ecosystem. *Journal of Mountain Science*, 08, 62-74

Chandra, A., Pardha Saradhi, P., Maikhuri, R.K., Saxena, K.G., Rao, K.S. 2010a. Assessment of Monetary Budget in Traditional Agrodiversity Management: A case Study of central Himalayan Village ecosystem. *Phytomorphology, 60*, 137-149

Chandra, A., Pardha Saradhi, P., Rao, K.S., Saxena, K.G., Maikhuri, R.K. 2011a. An Investigation into the Energy Use in Relation to Yield of Traditional Crops in Central Himalayas, India, *Biomass and Bioenergy* 35, 2044-2052

Chandra, A., Rakesh, Kandari, L. S., 2009b. Role of rural and tribal women in conservation of village ecosystem: A case study of Nanda Devi Biosphere Reserve, India, *Environment & We: An International Journal Science & Technology*, 4, 29-34

Chandra, A., Sharmila, P., Pardha Saradhi, P., Rao, K.S., Saxena, K.G., Kandari, L. S., Payal K.C., Maikhuri, R.K. 2009a. Assessment of Biological Yield of Some Selected *Vigna* sps. with Native *Rhizobial* Strain in Traditional Agroecosystem of Central Himalaya. *Proceeding of International Conference on Changing Environmental Trends and Sustainable Development*, Hisar. 217-221

Chethan, S., Malleshi, N.G. 2007. Finger millet polyphenols: Characterization and their nutraceutical potential, *American Journal Food Technology*, 2 (7), 582-592.

Chu, G.X., Shen, Q.R., Cao, J.L. 2004. Nitrogen fixation and N transfer from peanut to rice cultivated in aerobic soil in intercropping system and its effect on soil N-fertility. *Plant and Soil* 263, 17–27.

Dapaah, H.K., Asafu-Agyei, J.N., Ennin, S.A., Yamoah, C.Y. 2003. Yield stability of cassava, maize, soybean and cowpea intercrops. *The Journal of Agricultural Science Cambridge* 140, 73–82.

Gopalan, C., Ramashastri, B.V., Balasubramaninan, S.C., Rao, B.S.N., Deosthale, Y.G., Pant, K.C. 2004. Nutritive Value of Indian Foods, National Institute of Nutrition, Hyderabad, India. pp 161.

Hauggaard-Nielsen, H., Jensen, E.S. 2001. Evaluating pea and barley cultivars for complementarity in intercropping at different levels of soil N availability. *Field Crops Res*earch, 72, 185–196.

Haymes, R., Lee, H.C. 1999. Competition between autumn and spring planted grain intercrops of wheat (*Triticum aestivum*) and field bean (*Vicia faba*). *Field Crops Res*earch. 62, 167–176.

Jensen, E.S., 1996. Grain yield, symbiotic N_2 Fixation and interspecific competition for inorganic N in pea-barley intercrops. *Plant and Soil,* 182, 25–38.

Keerio, H.K., Aslam, 1986. Intercropping in maize crop, Maize Production Manual, PARC, Islamabad pp.1-4.

Maikhuri, R.K., Rao, K.S., Saxena, K.G 1996. Traditional crop diversity for sustainable development of Central Himalayan Agroecosystems, *International Journal of. Sustainable Development and World Ecology,* 3, 8–31.

Maikhuri, R.K., Rao, K.S., Saxena, K.G., Semwal, R.L. 1999. Traditional Crop Diversity Based Nutrition and the Prospects for Sustainable Rural Development in the Central Himalaya. *Himalayan Paryavaran* 6, 36-42.

Maikhuri, R.K., Rao., K.S., Semwal, R.L., 2001. Changing scenario of Himalayan agroecosystems: loss of agrobiodiversity, an indicator of environmental change in Central Himalayas. *The Environmentalist* 21, 23-39.

Maikhuri, R.K., Semwal, R.L., Rao, K.S., Nautiyal, S., Saxena, K.G. 1997. Eroding traditional crop diversity imperils the sustainability of agricultural systems in Central Himalaya. *Current Science,* 73, 777–782.

Ode, P.E., 1991. Evaluation of short and tall sorghum varieties in mixtures with cowpea in the Sudan savanna of Nigeria: Land equivalent ratio, grain yield and system productivity index. *Experimental Agriculture* 27, 435–441.

Saxena, K.G., Maikhuri, R.K., Rao, K.S. 2005. Changes in agricultural biodiversity: Implications for sustainable livelihood in the Himalaya. *Journal of Mountain Science,* 2, 23–31.

Semwal, R.L., Maikhuri, R.K., Rao, K.S., Singh, K., Saxena, K.G. 2002. Crop productivity under differently lopped canopies of multipurpose trees in Central Himalaya, India. *Agroforestry System* 56, 57–63.