Productivity improvement in upland rice through the inclusion of legumes, in the far-western mid-hill areas of Nepal

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Abstract

This study was carried out with the objectives of improving soil fertility and enhancing the productivity of upland rice in Nepal, by identifying both higher yielding land races of upland rice and summer legumes that could be grown as an intercrop in the upland rice production systems. Local landraces of legumes and upland rice were collected from the mid-hills and tar (river basin) areas of Nepal. These land races were evaluated and selected for agronomic characters that are suitable for the intercropping production system. Intercropping experiments using the selected land races of upland rice and legumes were conducted over 3 years (1999/00-2001/02) at on-station and on-farm sites in the far-western mid-hills of Nepal. The upland rice (*Oryza sativa* L.)-Damari, soybean (*Glycine max* L.)-Sathiya and black gram (*Vigna mungo* L.)-Maintada local exhibited the best performance in the intercropping system. The land equivalent ratios (LER – the ratio of total yield from intercropping with that of sole crop yield) were found to be 1.89 and 1.82 for upland rice intercropped with black gram (Maintada local) in the ratio (rice:legume rows) of 3:2 and 4:2. A LER value of 1.65 was obtained from upland rice and soybean (Sathiya) grown as a 3:2 intercrop. Considering the soil fertility status of the experimental sites, fertility trends indicated an immediate increase in available phosphorus after fertilization as well as favourable trends in total nitrogen and organic matter. The investigation has indicated that the continuous inclusion of legumes may have a positive impact on soil fertility, resulting in the sustainable productivity of upland rice.

Introduction

Rice, the most important crop in Nepal, is widely cultivated in both the upland and lowland eco-systems. Upland ice occupies about 9% of the total rice area. Rice grown in the uplands (*Bari*, which denotes land with no irrigation facilities) is invariably rainfed while the rice in the lowland areas (*Khet*) is grown both in rainfed and irrigated (paddy) conditions. *Ghaiya* is the Nepali term for upland rice, the growing period of which coincides with the monsoon season. A broadcasting method of sowing is generally followed in the mid- and far-western hills of Nepal. The production system is based on the traditional practice of growing a sole crop in the monsoon (summer) season with local land races of upland rice and very low or no application of fertilizers. With the continuous production of rice without the inclusion of legumes, both soil fertility and upland rice productivity have been decreasing steadily, a situation that needs to be improved. Consequently, recent investigations at the Agriculture Research Station at Surkhet were focussed on improving soil fertility and enhancing upland rice crop productivity by identifying summer legumes and suitable high-yielding land races of upland rice that could be grown as an intercrop. On-farm and on-station experiments have been conducted for 3 years (1999/2000-2001/2002). On-farm experiments were carried out in farmers' fields in the Surkhet and Dailekh districts, while the on-station experiments were conducted in the research block at the ARS, Surkhet. In this paper, an account is given of these experiments.

Materials and methods

Collection and screening of local land races

During 1999/2000, local landraces of summer legumes and upland rice suitable for intercropping were collected from the mid-hills and tar (river basin) areas of Nepal. The collected land races were evaluated and screened in replicated single rows. Most of the land races were selected on the basis of phenotypes that are associated with their agronomic worth when intercropping upland rice with legumes, such as a determinate/bushy type of legume and a dwarf/non-lodging type of upland rice.

Field experimentation

On-station experiments (randomised complete block design, 3 replicates) were undertaken at the ARS Surkhet, and on-farm experiments were conducted in the Surkhet and Dailekh districts of Nepal. There were a total of 17 intercropping treatments comprising upland rice (Damari cultivar) sown with the summer legume soybean (Sathiya) or black gram (Maintada local or Latikoeli local) in 2:2, 3:2 and 4:2 (rice:legume rows) ratios. Fertilizer for rice was applied @ 60:40:20 NPK kg/ha with 30:40:20 NPK kg/ha as a basal dose and 30 N kg/ha topdressed 35 days after sowing. For black gram and soybean, fertilizer was applied @ 30:40:30 NPK kg/ha as a basal dressing. The plot size of a sole crop (no legume) of upland rice was 6 rows x 5 m with the rows spaced 25 cm apart. Likewise, the sole crops of both soybean and black gram were sown in plots of 6 rows x 5 m 50 cm apart and their plant-to-plant distance was maintained at 15 cm by thinning. Recommended crop management practices were followed during the whole crop growth period.

Assessment of fertility status of soil

Prior to the laying out the experiments, soil samples were collected from the station as well as from different farmers' fields to determine the baseline soil fertility status. Also, soil samples were collected each year from all the experimental sites after the harvest of the rice crop, to determine the impact of legume intercropping. Collected soil samples were analyzed in the laboratory and chemical properties were assessed using standard laboratory methods Assessed chemical properties were soil reaction (pH), organic matter, total nitrogen, available phosphorus, available potash, electrical conductivity (EC), particle size distribution and textural class. When assessing the soil reaction and nutrient status, the standard rating chart of the soil science division of NARC was followed.

Results and discussion

Among the 25 lines of local landraces that were tested, the Latikoili local and Maintada local varieties of black gram performed best in the intercropping system, and Sathiya was identified as the most suitable landrace of soybean for intercropping with upland rice. Black gram (Maintada local) was determinate in habit whereas flowering/maturity in the Latikoili local variety was not synchronized. Based on their yield performance and agronomic characters, the above legume land races were selected and included in the study of intercropping with the upland rice variety Damari, which was selected from 3 genotypes of local land races of upland rice. The sole crop (no legume) of upland rice (Damari) produced a significantly higher grain yield (1.227 t/ha) than the other 2 land races of upland rice.

The sole crops of soybean, Maintada local (0.898 t/ha) and Latikoeli (0.828 t/ha), were comparable, and a similar yield was also recorded for the combination of black gram (Maintada local) with rice in the 3:2 and 4:2 intercrop treatments. The combination of black gram (Maintada local) with rice in the ratios of 3:2 or 4:2 was preferred by most of the farmers. The Land Equivalent Ratios (LER – the ratio of total yield from intercropping with that of sole crop yield) of upland rice in combination with black gram (Maintada local) were found to be 1.89 (3:2 treatment) and 1.82 (4:2 treatment) followed by a LER of 1.752 for rice intercropped with black gram (Latikoili local) in 4:2 ratio and a LER of 1.65 for rice with soybean (Sathiya) in 3:2 ratio – these combinations were not statistically different (Table 1).

Table 1. Performance of inter-cropping of upland rice with summer legumes.

#	Treatments	Varieties	Line ratio	Grain Yield (t/ha)	Days to flowering	Days to maturity	LER
13	Upland rice: Black	Rice (Damari)	3:2	1.040	80	107	1.89

	gram	Black gram (Maintada)		0.937	44	99	
14	Upland rice: Black gram	Rice (Damari)	4:2	1.013	83	107	1.82
		Black gram (Maintada)		0.891	44	99	
8	Upland rice: Black gram	Rice (Damari)	4:2	0.974	82	107	1.75
		Black gram (Latikoili)		0.766	49	105	
10	Upland rice: Soybean	Rice (Damari)	3:2	0.902	84	107	1.65
		Sathiya		0.902	62	136	

Soil fertility trends

At all of the on-farm and on-station experiment sites, there was no trend over time in the soil pH (Table 2). The organic matter content slightly increased over the 3 years with, in some cases, a slight decrease in the first year. It is expected that there will be a slow build-up in the organic matter status of the soils with the inclusion of legumes in the system, significantly improving the OM level in the soils in the long run. The total nitrogen content was also slightly increased after the three years experimentation, indicating a positive impact of legumes on the nitrogen status of soils. Compared with the baseline values, the available phosphorus levels increased noticeably after the first-year rice harvest, a response to the application of phosphoric fertilizers in the experiment. Farmers usually do not apply fertilizers but legumes need relatively higher amounts of P and hence it was applied. The levels of available potassium showed a decreasing trend, possibly indicating the need to apply potassium-containing fertilizers to the soils (Table 2).

Table 2. Trends of soil fertility status.

No.	**Location**	**pH**				% OM			
		Baseline	Year I	Year II	Year III	Baseline	Year I	Year II	Year III
1	Farmer's field Surkhet	6.1	6.0	6.1	6.8	2.15	2.70	2.53	2.18
2	Farmer's field Dailekh	6.2	6.2	6.1	6.1	3.22	2.93	3.23	3.08
3	ARS, Surkhet	6.5	6.7	6.4	6.0	3.5	3.0	3.9	3.6

Location	% N				$P_2 0_5$ kg/ha				$K_2 0$ kg/ha			
	Base line	Year 1	Year II	Year III	Base line	Year 1	Year II	Year III	Base line	Year 1	Year II	Year III
Farmer's field Surkhet	0.14	0.12	0.13	0.15	19	76	56	47	448	368	344	411
Farmer's field Dailekh	0.16	0.14	0.16	0.16	23	78	61	59	613	610	414	391
ARS Surkhet	0.18	0.16	0.19	0.18	18	75	69	63	430	270	280	327

Conclusions

The results of the intercropping study revealed that upland rice (Damari), black gram (Maintada local) and soybean (Sathiya local) were identified as best land races among the all the tested genotypes. Black gram (aintada local) and soybean (Sathiya) were found suitable in the intercropping system due to their agronomic characteristics and fit for intercropping. Intercropping of summer legumes (blackgram-Maintada local or soybean-Sathiya) with upland rice in ratios of 3:2 and 4:2 were identified as the best intercropping combinations, producing a Land Equivalent Ratio >1.8, which is economically profitable for the growers of the far-western mid-hills of Nepal. Short-term trends in total nitrogen and organic matter indicated potential long-term improvements along with the increased available phosphorus. These results indicated that the continuous inclusion of legumes might reverse the decline soil fertility, thereby resulting in the sustainable productivity of upland rice.

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