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Productivity, competition behaviour and weed dynamics of various row proportions of maize (*Zea mays*)-legumes intercropping in Arunachal Pradesh

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ABSTRACT

Intercropping is the simultaneous cultivation of more than one crop species on the same piece of land and is regulated as the practical application of basic ecological principles such as diversity, competition and facilitation. Farmers of the region sow many crops in a piece of land, without following any row proportion geometrics and hence crop productivity is considerably low. A research was carried out to assess the feasibility of raising intercrops in association with maize (*Zea mays* L.) at ICAR Research Complex for NEH Region, Basar during 2010 and 2011. The results indicated that biomass accumulation was the highest with 1:1 than in the 1:5 row proportions. Leaf area index of maize with intercrop was the highest with 1:5 row proportions. The maize grain yield was obtained relatively higher with solitary maize followed by 1:2 of maize-soybean [*Glycine max* (L.) Merr.]. Maize equivalent yield was 55.5% higher with 1:5 of maize-groundnut (*Arachis hypogaea* L.) over the solitary maize, consequently, production efficiency was remarkably improved by 48.9% with 1:5 of maize-groundnut. Land equivalent ratio, area time equivalent ratio and monetory advantage index were favourable for the intercropping implying their intrinsic advantage over solitary planting. Weed density and dry biomass were lower with 1:5 row proportions which resulted in higher weed smothering efficiency.

Key words: Competition indices, Intercropping, Maize-legume, Productivity, Weed dynamics

Intercropping, the real-time cultivation of more than one species with distinct row proportion in the same field for efficient utilization of resources; cause more stable yields and a method to reduce problems of abiotic and biotic stress, and nutrient losses (Marer *et al.* 2007; Vestrager *et al.* 2008). In maize (*Zea mays* L.) based intercropping system, selection of an appropriate intercrop having desirable plant type and growth pattern has great importance. Resource utilization mainly depends on selection of intercrops and ideal species leads to higher biological efficiency and yield advantages (Agegnehu *et al.* 2006). Maize being a rainy season and widely spaced crop severely suffered with weeds, which caused 30-70% yield loss (Hugar and Palled 2008). However, intercropping of legumes provides the opportunities to suppress the weeds which in turn reduced in weed biomass (Banik *et al.* 2006). Productivity per unit area could be increased through suitable crops having higher yield stability and adoption of appropriate intercropping patterns.

This also provides higher yield component and more remunerative (Ghosh 2004). A suitable intercropping provides a yield advantage over sole cropping, because the component crops utilize the natural resources in such a way that they are able to complement with each other (Dhima *et al.* 2007). Comparison of intercropping with single indices is not a good option therefore, possible all the option need to be tested to come into conclusion. A number of indices such as land equivalent ratio, area time equivalent ratio and monetary advantage index have been proposed to describe competition within and economic advantages of intercropping systems (Ghosh 2004, Banik *et al.* 2006, Dhima *et al.* 2007). These are the matter of investigation with new crop combinations and spatial arrangement in intercrops. Hence an intercropping experiment was conducted to investigate the effect of maize-soybean/ groundnut intercropping on productivity, competition indices and weed dynamics in Arunachal Pradesh.

MATERIALS AND METHODS

The field experiment was conducted in silty loam soil at the Research Farm of ICAR Research Complex for NEH Region, Basar, (27°95'N latitude and 94°76'E longitude, 660 m above MSL), during April- August of 2010 to 2011. The area falls under humid sub tropical climate. The weather status during experimental period is given in Fig 1. The soil of experimental site was acidic in reaction (pH 5.3), high in organic carbon (Walkaley and Black, 13.2 g/kg), low in available nitrogen (alkaline permanganate N, 193.8 kg/ha),

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low in available phosphorus (Bray P, 8.4 kg/ha) and medium in available potassium (ammonium acetate K, 210.5 kg/ ha). The experiment was laid out in a randomized block design with three replications with gross plot size of 4.8 × 4.0 m^2. There were nine treatment combinations, where maize (55 000 plants/ha), soybean [*Glyaine max* (L.) Merr.] and groundnut (*Arachis hypogaea* L.) (3 33 000 plants/ha) were planted solitary and maize with three different row proportions [1:1 and 1:2 in additive series (100:31 and 100:62 proportion respectively), and 1:5 in replacement series (with 66:77 proportion)]. The recommended basal dose of fertilizer for maize (40:60:40 kg NPK/ha), soybean and groundnut (25:60:40 kg NPK/ha) in the form of urea (46% N), single super phosphate (16% P) and muriate of potash (60% K), respectively were applied just prior to sowing and 40 kg N/ha was top dressed at 40 days after sowing (DAS) in maize. However, fertilizers were applied as per proportionate to the sole population for main and intercrop separately.

Weed density was measured from 0.5 m^2 randomly selected in each plot at 45 DAS and grouped into grasses, sedges and broadleaved and extrapolated to 1.0 m^2. Weeds were dried in the oven at 70°C for 72 hr to determine weed dry biomass and weed smothering efficiency (WSE) were recorded as described below:

WSE (%) = [(Weed dry biomass of solitary maize-weed dry biomass of intercrop)/ Weed dry biomass of sole maize]*100

Competition indices were recorded as per the standard formula. The results were statistically analyzed with GLM procedure using SAS 9.2 programme (SAS 2010). The significance of treatment effects was determined using the *F*-test. The significance of the difference between means of two treatments was tested using least significant difference (LSD) at 5% probability level.

RESULTS AND DISCUSSION

Growth attributes

Growth attributes significantly ($P<0.05$) influenced by intercropping and their row proportions (Table 1). Solitary maize recorded lowest dry biomass accumulation, whereas 1:5 of maize-soybean had highest biomass accumulation, it is often a result of better use of available resources. Although other intercrop combinations with maize improved the biomass accumulation, yet their effect was marginal. Comparatively soybean has accumulated higher dry biomass than groundnut. It was also evident that 1:1 row proportion of intercrop had higher biomass than the 1:5 row proportions. Leaf area index (LAI) of maize and intercrop were higher under maize with 5>2>1 row proportions of intercrop. However, soybean recorded comparatively higher LAI than the groundnut. Increase in LAI allowed the plant to capture more solar radiation with enhanced photosynthesis that further helped in better translocation of photosynthates in higher dry matter production (Hugar and Palled 2008).

Yield and maize equivalent yield

The individual yield of maize was higher under solitary maize, which was similar to 1:2 row proportions of maize-soybean and maize-groundnut (Table 2). Increase in yield under solitary maize was due to the fact that the wider available space in solitary maize reduced the competition for space, solar radiation and nutrients, which provides favourable environment to produce higher yield (Hugar and Palled 2008). However, yield reduction of maize was

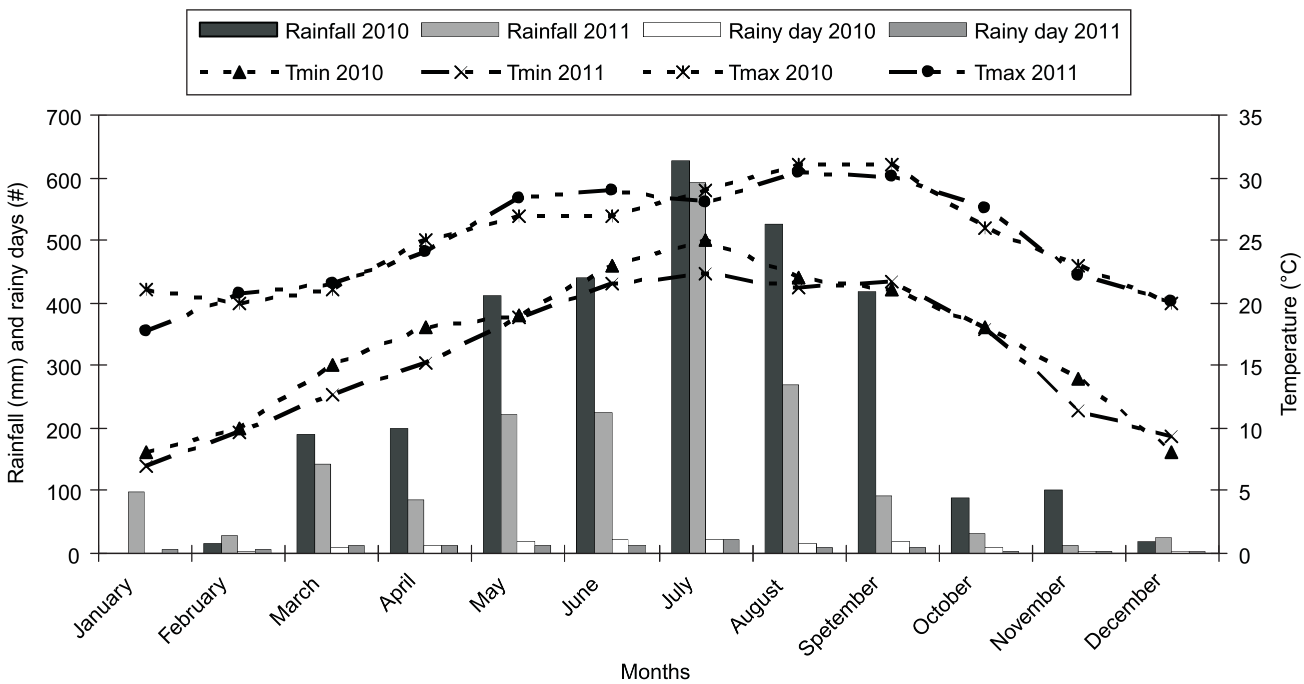

Fig 1 Rainfall prevailed during experimental period at experimental site

Table 1 Growth attributes as influenced by maize based intercropping (mean of 2010 and 2011)

Treatment	Biomass of maize (g/plant)	Biomass of intercrop (g/plant)	Leaf area index of maize	Leaf area index of intercrop	Total leaf area index
Sole maize	168.4		4.5		4.5
Sole soybean		28.6		6.3	6.3
Sole groundnut		24.3		4.9	4.9
1:1 of maize-soybean	172.3	32.5	5.2	7.4	12.6
1:2 of maize-soybean	175.4	31.2	5.5	7.0	12.5
1:5 of maize-soybean	178.3	29.1	5.9	6.5	12.4
1:1 of maize-groundnut	171.3	28.3	4.7	5.2	9.9
1:2 of maize-groundnut	174.3	26.7	4.8	5.7	10.5
1:5 of maize-groundnut	175.6	25.2	5.2	6.0	11.2
LSD (P=0.05)	4.88	1.26	0.33	0.42	

Table 2 Yield, maize equivalent yield and production efficiency as influenced by maize based intercropping (mean of 2010 and 2011)

Treatment	Maize yield (t/ha)	Intercrop yield (t/ha)	Maize equivalent yield (t/ha)	Biological yield (t/ha)	Production efficiency (kg/ha/day)
Sole maize	4.00		4.00	9.64	31.5
Sole soybean		1.88	3.53	5.42	24.1
Sole groundnut		1.53	4.23	4.45	32.6
1:1 of maize-soybean	3.75	4.32	4.54	10.80	32.1
1:2 of maize-soybean	3.91	0.78	5.35	12.09	37.0
1:5 of maize-soybean	2.43	1.73	5.61	10.48	38.3
1:1 of maize-groundnut	3.52	0.36	4.60	10.28	35.9
1:2 of maize-groundnut	3.75	0.67	5.75	11.49	43.9
1:5 of maize-groundnut	2.30	1.31	6.22	9.33	46.9
LSD (P=0.05)	0.157	0.930	0.202	0.369	1.50

noticed with 1:5 row proportions, this because of reduction in plant density of maize. The shading effect curtailed efficient utilization of natural resources and restricted growth of maize resulted in more yield in intercrop (Hussain *et al*. 2003, Agegnehu *et al*. 2006, Haque *et al*. 2008). In intercropping, yield of component crop was highest with 1:5 row proportion of maize-soybean followed by 1:5 of maize-groundnut. Similarly, stover yield was highest with 1:2 of maize-soybean and stover yield of intercrop increased at higher row proportion. On the other hand, biological yield was highest with 1:2 of maize-soybean followed by 1:2 of maize-groundnut. The maize equivalent yield (MEY) and production efficiency (PE) followed the similar trend and were achieved 55.5 and 49.0% respectively higher with 1:5 of maize-groundnut followed by 1:2 of maize-groundnut (43.7 and 39.3% respectively) and 1:5 of maize-soybean (40.4 and 21.6% respectively) than the solitary maize. The lower MEY and PE were with solitary maize might be due to lower market price of maize than component crops. Similar findings corroborated by Haque *et al*. (2008).

Competition indices

Competition indices significantly ($P<0.05$) influenced by intercropping of maize with soybean and groundnut at various row proportions (Table 3). Numbers of indices were developed to compare the best possible combination of sole and intercrop to assess the economic feasibility of the system along with area and time (Hayder *et al.* 2003). Land equivalent ratio (LER) reflected the extra advantages of intercropping system over solitary planting. Results indicated that LER of maize-soybean increased from 17-53%. In general, it was noticed that with increase of row proportion, LER also got improved. This provided an accurate assessment of the competitive relationship between the component crops (Chen *et al.* 2004, Esmaeil *et al.* 2010).

Area time equivalent ratio (ATER) provides more realistic comparison of the yield advantage of intercropping over solitary planting in terms of area and time dimension as well as the overall productivity of the intercropping system (Hayder *et al.* 2003). ATER was higher and ranges from 7.1-45.2% with maize-soybean and 10.8-40.8% with maize-groundnut at different row proportion than the solitary maize. It was noticed that as row proportion of intercrop increased with maize ATER gradually increased. Aggressivity is important parameter to assess the dominance of the crop species in intercropping. Maize was less dominant with 1:5 of maize-soybean followed by 1:5 of maize-groundnut. This was mainly due to lower maize and higher intercrops density in given area. But, soybean appeared to use light with greater efficiency over groundnut thus recorded higher yield. Similar finding was corroborated by

Table 3 Intercropping indices as influenced by maize based intercropping (mean of 2010 and 2011)

Treatment	Land equivalent ratio	Area time equivalent ratio	Aggressivity	Competition ratio of maize	Competition ratio of intercrop	Monetary advantage index
1:1 of maize-soybean	1.17	1.071	5.32	1.28	1.59	1812.05
1:2 of maize-soybean	1.40	1.277	39.00	1.46	2.08	3606.20
1:5 of maize-soybean	1.53	1.452	19.31	0.85	1.29	4423.45
1:1 of maize-groundnut	1.12	1.108	3.12	1.16	1.47	1786.05
1:2 of maize-groundnut	1.38	1.347	14.07	1.33	1.95	4886.25
1:5 of maize-groundnut	1.43	1.408	10.58	0.86	1.30	5350.60
LSD (P=0.05)	0.056	0.0557	5.215	0.076	0.066	600.665

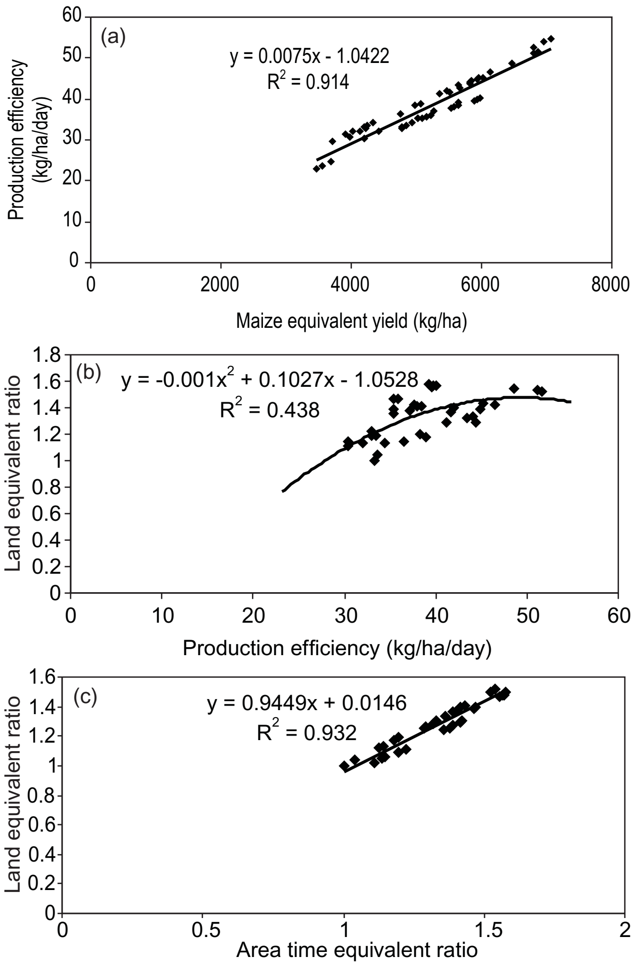

Fig 2 Maize-soybean/groundnut intercropping system influenced the relationship between a) maize equivalent ratio (MER) and production efficiency, b) production efficiency and land equivalent ratio (LER) and c) area time equivalent ratio (ATER) and land equivalent ratio.

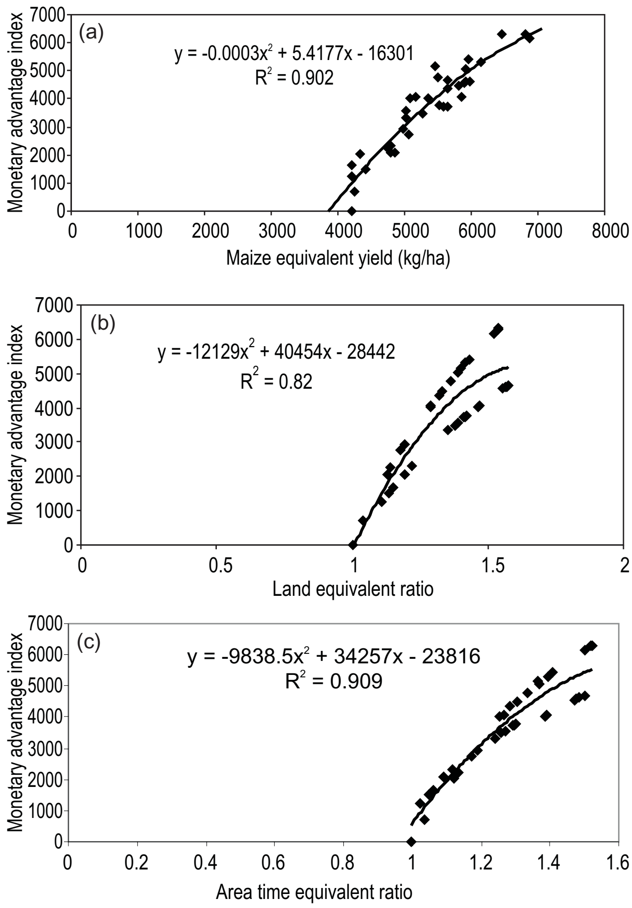

Fig 3 Maize-soybean/groundnut intercropping system influenced the relationship of monitory advantage index with a) maize equivalent yield (MEY), b) land equivalent ratio (LER) and c) area time equivalent ratio (ATER)

Pandita *et al.* 2000.

The competition ratio (CR) of maize was higher with 1:2 of maize-soybean followed by 1:2 of maize-groundnut and lower CR obtained with 1:5 of maize-soybean. Similarly, CR of intercrop was higher with 1:2 of maize-soybean followed by 1:2 of maize-groundnut, and lower CR with 1:5 of maize-soybean. Table 3 depicted that the highest monetary advantage index (MAI) was obtained with 1:5 of maize-groundnut followed by 1:2 of maize-groundnut. However, lower MAI recorded with 1:1 of maize-groundnut and 1:1 of maize-soybean. MAI was mainly influenced by market price of produce and economic yield harvested, resulted in higher MAI. Similar finding was corroborated by Ghosh (2004).

It is well evident that, most of the competition indices were registered better with 1:2 of maize-soybean followed by 1:2 of maize-groundnut. This was due to higher yield of

Table 4 Weed density, dry biomass and weed smothering efficiency as influenced by maize based intercropping (mean of 2010 and 2011)

Treatment	Weed density (m^2)	Weed dry weight (g/m^2)	Weed smothering efficiency (%)
Sole maize	11.5 (131.2)	6.3 (39.2)	66.7
Sole soybean	6.1 (36.0)	3.7 (13.0)	55.9
Sole groundnut	7.0 (48.4)	4.2 (17.2)	28.3
1:1 of maize-soybean	10.2 (103.3)	5.3 (27.9)	40.0
1:2 of maize-soybean	8.9 (78.0)	4.9 (23.4)	56.4
1:5 of maize-soybean	6.8 (46.0)	4.2 (17.0)	16.3
1:1 of maize-groundnut	10.4 (108.0)	5.8 (32.5)	32.7
1:2 of maize-groundnut	8.9 (78.8)	5.2 (26.0)	42.8
1:5 of maize-groundnut	8.2 (66.4)	4.8 (22.2)	66.7
LSD (P=0.05)	0.54	0.42	10.23

maize and additional intercrop yield was harvested at 1:2 row proportions. Some of the indices were recorded better with 1:5 row proportions, because of market price of intercrops were higher than maize. But, almost all the indices were registered better with 1:2 row proportions of maize with soybean and groundnut. Similar finding was also reported by Mahapatra (2011).

Relationship between various indices were studied, Fig 2a depicted that MEY and PE followed the positive linear relation with R^2 =0.91, it depicted that as MEY increased PE linearly increased. LER showed the quadratic relationship with production efficiency with R^2 =0.44, but was positively linear relationship with ATER with R^2 = 0.93 (Fig 2b). It depicted that as LER increased ATER also improved (Fig 2c). However, MAI followed the quadratic relationship with MEY with R^2=0.90 (Fig 3a), LER with R^2 =0.82 (Fig 3b) and ATER with R^2 =0.91 (Fig 3c). This clearly showed that MEY, LER and ATER gradually increased with increase in MAI.

Weed dynamics

The major weed flora observed in the experimental plots included *Ageratum conyzoids*, *Crommolina odorata*, *Galinsoga parviflora*, *Boreria hispida, Degiteria singuanalis*, *Cynodan dactylon* and *Cyperus rotundus*. Intercropping of soybean and groundnut significantly reduced the weed density and dry biomass than in solitary maize (Table 4). Solitary maize has higher weed density followed by 1:1 row proportion of maize with groundnut and soybean. Solitary soybean reduced 88.5% of weed density followed by solitary groundnut (64.5%) over solitary maize. Weed dry biomass followed the trend of weed density and solitary maize has recorded the highest. However, solitary soybean reduced the weed biomass by 70.2% followed by solitary groundnut (50.0%). Reduction in weed dry biomass was mainly due to shading effect and competition stress created by the canopy of intercrop and suppressive effect on associated weeds (Pandey *et al.* 2003, Banik *et al.* 2006). Solitary soybean registered 66.7% weed smothering efficiency followed by 1:5 of maize-soybean (56.4%) and solitary groundnut (55.9%) over solitary maize. The better canopy coverage reduced the available space and interception of solar radiation in between crop rows helped in lower weed density and biomass and ultimately higher WSE (Haque *et al.* 2008, Tripathi *et al.* 2008).

Based on result obtained from the study it could be inferred that, intercropping of maize with groundnut at 1:5 row proportions in eastern Himalaya have provided higher productivity. It was also noticed that, intercropping also suppresses the weeds better than the sole maize, resulted in improved yield benefits from the whole system. The results of economic indices also indicated that intercropping of maize with 1:5 of groundnut/soybean had better monetary advantages. As a companion crop, groundnut and soybean have contributed for the higher productivity and allowing better use of resources.

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