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Intercropping and rows configuration influence productivity of dryland groundnut (*Arachis hypogea* L.)

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ABSTRACT

Groundnut (*Arachis hypogea* L.) is one of the most important crops grown as sole or intercropped under rainfed condition in Northwestern Pakistan. There is lack of publish research to indicate better intercropping system for groundnut under rainfed condition. This research work was therefore designed to investigate groundnut intercropping in legumes and non-legumes crops for understanding and development of production technology for groundnut under rainfed areas where indiscriminate intercropping is practiced. Field experiments were conducted at the Agricultural Research Farm of The University of Agriculture Peshawar, Northwestern Pakistan, during summer 2008 and 2009. Goundnut (*Arachis hypogea* L.) intercropped in single and paired rows in different crops [two legume crops viz. guar (*Cyamopsis tetragonoloba* L.) and mungbean *(Vigna radiata* L.), two cereals crops viz. millet (*Pennisetum typhoides* L.) and sorghum (*Sorghum bicolor* L.) and one oilseed crop viz. sesame (*Sesamum indicum* L.) which is non cereal/non leguminous crop] was studied. Sorghum, millet and sesame as sole crops had depleted soil N contents form the initial value; however, improvement in soil N contents was observed when these crops were intercropped with groundnut. On the other hand, legumes sole crops had more soil N content, and the soil N content dropped in intercropped legumes. Sole groundnut had higher yield and yield components than groundnut intercropping in cereal crops. Groundnut grown in single row produced more pod plant^{-1}, pod yield and harvest index than paired rows configuration. The LER (land equivalent ratio) decreased in groundnut + cereal < groundnut + sesame < groundnut + legume intercropping. These results based on LER suggest the adoption of single row of groundnut intercropping preferably with legumes (mungbean and guar) and sesame than cereals intercropping.

Key words: groundnut, yield, rows configuration; intercropping; legumes; cereals; sesame; land equivalent ratio, dryland

1. INTRODUCTION

To enhance crop production per unit area, inter planting two or more species in rainfed (moisture stress) area is widely practiced in many developing countries (Francis, 1986; Burton et al., 1992); including Pakistan and the objectives vary from locality to locality. Intercropping is one of the oldest means of reducing the risk factor in the subsistence farming of the rainfed area. Increase in land use efficiency (Ofori and Stern, 1987); depression of weeds growth (Hauggaard-Nielson et al., 2001 a); nitrogen fixation (Jenson, 1996; Hauggaard-Nielson et al., 2001 b) and some favorable exudates from the legumes as intercropping component (Willey, 1979; Ofori and Stern, 1987) and greater yield stability (Jensen, 1996) have been reported. The presence of other plants of the same or different species modified the growth and development of plants, under field conditions due to the allelopathy and competition (Rice, 1984). Buildup of phytotoxins and harmful microbes in soil, resulting in phytotoxicity and soil sickness due to continuous monocultures have been reported by Narwal (2004). Olofsdotter (1998) and Wu et al. (1999) are of the opinion that reliance on traditional herbicides in crop production can be reduced by growing crops having allelopathic properties and reducing pollution (Norwal et al., 1998) as crops are easily biodegradable and less polluting than the traditional herbicides.

Total interplant yield is sometimes more productive per unit of land than the average of these crops in monoculture (Cordero and McColum, 1979; Crookston and Hill, 1979; Mohta and De, 1980; Allan and Obura, 1983; Elmore and Jackobs, 1984). Morris and Garrity (1993) have concluded that intercropping of legume and non legumes combination was superior to sole cropping in term of yield. The concept of growing tall and short crops in strips or alternate rows to maximize total production has been recognized from centuries and the practice is still common in agriculturally underdeveloped areas of the world (West and Griffith, 1992). Alternating single rows of corn and soybean increased corn yield by 26-35 % and decrease soybean yield by 22-35 % (Crookston and Hill, 1979). Francis et al (1986) concluded that alternative strip cropping is generally equal to or better than sole cropping, both in total production per unit area and in profit per unit area.

The present study was undertaken for two years to evaluate the benefit of the mutual association of legumes and non-legumes sown with different rows configuration. Groundnut (*Arachis hypogea* L.) basically a leguminous crop having quiet unique growth pattern as compared with other crops and was used as test crop. The study will help in the understanding and development of production technology for groundnut growing in rainfed areas where indiscriminate intercropping is practiced.

2. MATERIALS AND METHODS

Experimental site

A set of field experiments were conducted at the Agricultural Research Farm of The University of Agriculture Peshawar, Khyber Pakhtunkhwa, Pakistan, during summer 2008 and 2009. The experimental site is located at latitude of 34^0 N and 354 meter altitude. The area is mainly dry with mean annual precipitation of 441 mm having warm to hot, semi arid, sub tropical, continental climate. The mean maximum temperature in summer is 40 °C and the mean minimum temperature is 25 °C while in winter mean maximum temperature is 18°C and mean minimum temperature is 4 °C (Dept. of Meteorology, Pakistan).

Experimentation

The experiment was laid out in randomized complete block design with split plot arrangement. Intercropping of local groundnut (*Arachis hypogea* L.) cultivar with six different crops allotted to main plots, while row configurations of groundnut **(**single row vs. paired rows) were allotted to subplots. Three legumes (groundnut (*Arachis hypogea* L., guar (*Cyamopsis tetragonoloba* L.*),* mungbean *(Vigna radiata* L.), two cereals i.e. millet (*Pennisetum typhoides* L.), and sorghum (*Sorghum bicolor* L.) and one oil seed crop i.e. sesame (*Sesamum indicum* L.) which is non cereal/non leguminous crop in addition to the sole cropping of each crop were grown. Groundnut crop was sown by two different row planting configurations (i.e. single row and paired rows). In case of single row planting configuration spacing between the rows of groundnut were kept 50 cm, while in case of paired rows spacing configurations, row to row distance was reduced to 40 cm. The size of subplots was 3.6 m x 5 m having four replications. The numbers of plants per unit area was same in both row configurations. Nitrogen (N) as urea and phosphorus (P) as single super phosphate were applied according to the recommended doses of crop concerned when grown as a sole; while in intercropping with groundnut, NP recommended for groundnut were applied. The experiments were conducted at rainfed condition. The crops were sown on the residual moisture of the February-March rainfall and were raised on subsequent rainfall of Mansoon Season rainfall (July-August). The ratios of groundnut to the other crops in case of interplanting were 3:1. Different crops were sown on the same day (23rd May, 2008, 26th May, 2009) but were harvested on different dates. Crops were sown for two consecutive seasons. The soils have been developed in piedmont alluvium and are clay loams.

Soil nitrogen determination

Soil N contents were followed during the course of experiment (prior to sowing and after wheat harvest). Six composite sampling before sowing (at start of experiments) were collected up to the depth of 30 cm for N determination as baseline or bench mark. There- after soil samples were collected on sub plot basis after crop harvest at each season. These soil sampling were taken at depth of 0-30 cm from three spots within each sub plot and were thoroughly mixed. The sampling were air dried, finely ground sieved through < 0.2mm and analyzed for total N. Nitrogen concentration in soil was determined by Kjeldhal method (Bremner and Mulvaney, 1982).

The following treatments were used in the experiments:

Treatments

1. Groundnut Sole (Single row planting configuration)
2. Groundnut Sole (Paired rows planting configuration)
3. Sorghum Sole
4. Millet Sole
5. Mungbean Sole
6. Guar Sole
7. Sesame Sole
8. Groundnut (Single row planting configuration) + Sorghum
9. Groundnut (Single row planting configuration) + Millet
10. Groundnut (Single row planting configuration) + Mungbean
11. Groundnut (Single row planting configuration) + Guar
12. Groundnut (Single row planting configuration) + Sesame
13. Groundnut (Paired rows planting configuration) + Sorghum
14. Groundnut (Paired rows planting configuration) + Millet
15. Groundnut (Paired rows planting configuration) + Mungbean
16. Groundnut (Paired rows planting configuration) + Guar
17. Groundnut (Paired rows planting configuration) + Sesame

Statistical analysis of data

Data were analyzed statistically according to RCB design with split plot arrangement using Fishers Analysis of Variance Techniques. Least significant difference (LSD) test at 5 % probability level was employed upon obtaining significant differences among treatments means (Gomez and Gomez, 1983).

3. RESULTS

Soil N content had been affected by cropping system imposed (Table 1). In case of sole cereals (sorghum & millet) the N contents of soil were reduced from the initial contents of 221N g kg^{-1} by 5 and 8% due to growing of sorghum and millet, respectively. Intercropping of sorghum with groundnut not only regained N loss, but also improved the N soil content by 9.8%. However, reduction of 9% in N content was observed when millet was intercropped with groundnut. This reflects the differences within the two cereals in acquisition and utilization of nutrients. Calculating the effects of intercropping of groundnut with other legumes on N status, it was observed that groundnut + mungbean and groundnut + sesame cropping system has improved soil N by 20.7 and

32.2%, respectively than sole mungbean and sesame crops (Table 1). On the other hand, the soil N content of sole guar sole was 12.5% more than when it was intercropped with groundnut.

Significant differences ($P \leq 0.05$) in numbers of pods plant^{-1} and kernel weight was observed, while the numbers of plants m^{-2} was not significantly affected by different cropping system (Table 2). Groundnut grown as sole or intercropped with others crops (mungbean, guar or sesame) had significantly more pods plant^{-1} as compared with its intercropping with cereals (millet and sorghum). Both the cereals had adversely affected pods plant^{-1} when intercropped with groundnut. The effect of the cropping system was also significant on kernel weight of groundnut. Groundnut intercropped with other legumes (mungbean and guar) produced significantly heavier kernels than its sole growing or intercropping with millet, sorghum or sesame. The lowest kernel weight was recorded for groundnut when intercropped with sorghum (Table 2).

Mean value of the plots having groundnut sole had significantly more pod yield (2159 kg ha^{-1}) as compared with other cropping patterns, while lowest pod yield was obtained from the intercropping of groundnut with cereals (millet and sorghum) as shown in Table 3. After cereals, sesame + groundnut intercropping had significantly reduced pod yield when compared with sole groundnut or its intercropping with other legumes. Groundnut sole cropping although had maximum biological yield when compared with cereals or sesame but it was statistically at par with its intercropping with legumes (guar and mungbean). Harvest index (HI) was significantly lower in groundnut intercropped with sorghum and millet as compared with groundnut sole or intercropped with other legumes. The HI of groundnut sole crop was at par with those of guar, mungbean and sesame intercropping (Table 3).

The effect of row configurations on pods number, pod yield and HI was significant, while no significant effect on other parameters were observed (Tables 2 and 3). Groundnut grown in single rows had significantly higher number of pods plant^{-1} (31.4), pod yield (1891 kg ha^{-1}) and HI (24.5%) than the groundnut sown paired rows configuration (Table 2). Significant interaction between year (Y) x intercropping (I), and I x row configuration (R) for grain weight was observed. The three way (Y x R x I) interaction was significant for grain weight and pod yield (Tables 2 & 3).

Table 1 Cumulative soil N (g kg^{-1}) after harvest of different crops at the end of experiments

Treatments	N (g kg^{-1})	Treatments	N (g kg^{-1})
Groundnut Sole	261	Groundnut+ Sorghum	245
Sorghum Sole	210	Groundnut+ Millet	201
Millet Sole	182	Groundnut+ Mungbean	406
Mungbean Sole	425	Groundnut + Guar	322
Guar Sole	361	Groundnut + Sesame	310
Sesame Sole	210	Before crops sowing	221

Table 2 Plant m^{-2}, pods plant^{-1} and 100 kernels weight (g) of groundnut as affected by intercropping and rows configuration

Intercropping(I)	Plant m^{-2}	Pods plant^{-1}	100 kernels wt (g)
Groundnut Sole	8.7	24.4 a	54.7 bc
Groundnut + Sorghum	8.1	19.4 b	52.9 c
Groundnut + Millet	8.2	15.8 b	55.8 bc
Groundnut + Mungbean	8.4	23.9 a	60.5 a
Groundnut +Guar	8.5	24.0 a	57.4 a
Groundnut+ Sesame	8.4	24.8 a	55.9 bc
Row Configurations (R)			
Groundnut Single Row	8.4	31.4 a	57.1
Groundnut Paired Rows	8.3	22.1 b	55.3
Years (Y)			
Year-I	8.3	23.5	44.6 b
Year- II	8.3	20.0	52.2 a

Interactions			
Y x I	ns	ns	ns
I x R	ns	ns	*
Y x R x I	ns	ns	*

Means with different letters within column are significant at p=0.05 using LSD.
* = Significant and ns= not significant

Table 3 Pod yield (kg ha^{-1}), biological yield (kg ha^{-1}) and harvest index of groundnut as affected by intercropping and plant configuration

Intercropping (I)	Pod yield (kg ha^{-1})	Biological yield (kg ha^{-1})	Harvest index (%)
Groundnut Sole	2159 a	8695 a	24.8 a
Groundnut + Sorghum	1396 d	7458 c	18.7 b
Groundnut + Millet	1328 d	7261 c	18.2 b
Groundnut + Mungbean	1978 b	7854 b	25.2 a
Groundnut +Guar	1941 b	8198 a b	24.0 a
Groundnut+ Sesame	1750 c	6656 d	26.2 a
Row Configurations (R)			
Groundnut Single Row	1891 a	7784	24.5 a
Groundnut Paired Rows	1627 b	7924	20.9 b
Years (Y)			
Year-I	1800	7754	23.4
Year- II	1718	7954	21.9
Interactions			
Y x R x I	*	ns	ns

Means with different letters within column are significant at p=0.05 using LSD
*= Significant and ns= not significant.

Table 4 Effect of intercropping and rows configuration on land equivalent ration (LER) of rainfed groundnut

Treatments	Single rows	Paired rows	Means
Groundnut Sole	1.00	1.00	1.00
Groundnut + Sorghum	1.44	1.59	1.51
Groundnut + Millet	1.65	1.50	1.57
Groundnut + Mungbean	1.88	1.72	1.80
Groundnut + Guar	2.11	1.80	1.95
Groundnut + Sesame	1.60	1.73	1.69
Means	**1.60**	**1.57**	

SRC=Single Row Configuration PRC=Paired Rows Configuration

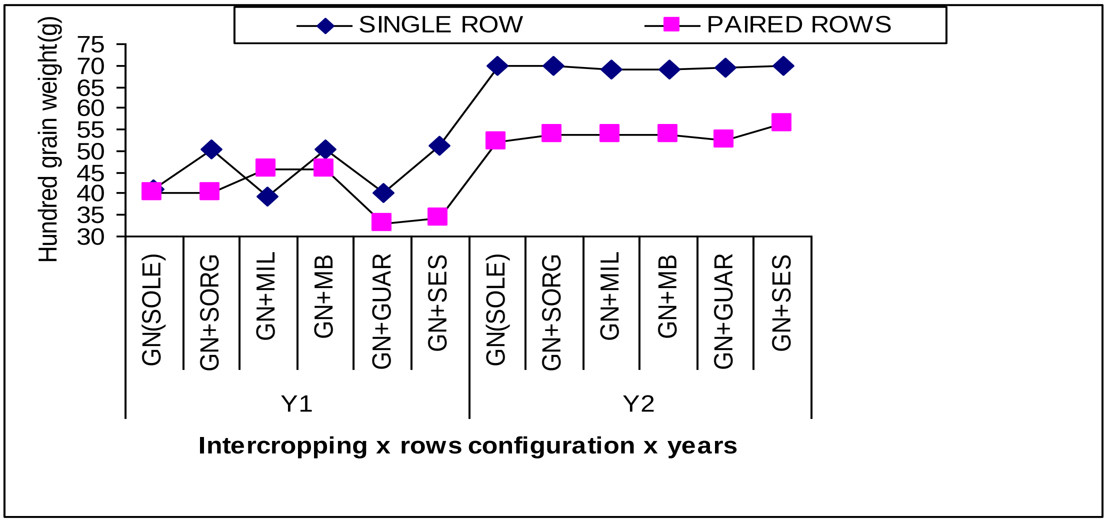

Figure 1 Kernel weight of groundnut as affected by years, intercropping and rows configuration

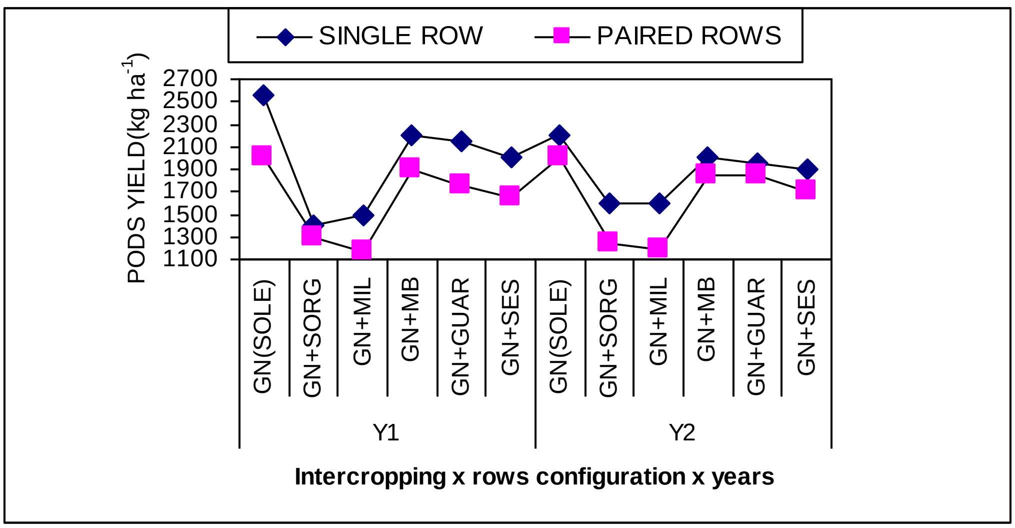

Figure 2 Pod yield (kg ha^{-1}) of groundnut as affected by years, intercropping and rows configuration

Kernel weight of groundnut as affected by I x R (Fig 1) indicated that in case of single rows configuration, grain weight was similar in intercropping of groundnut with sorghum, millet, guar and sesame, while significant increase in kernel weight was recorded only for groundnut + mungbean intercropping. Kernel weight of groundnut with paired rows was higher for the two cereals (millet & sorghum) and one legume (mungbean), while its weight drastically reduced when groundnut was grown in single rows in association with guar or sesame. The three way interaction (Y x R x I) for kernel weight indicated that second year was more suitable for groundnut to produce heavier kernels as compared with the first year of the experiment (Fig 2). No differences was observed in kernel weight between the rows configuration in the first year, but in the second year, single row configuration was far better in terms of kernel weight than paired rows (Fig 2). The three way interaction (Y x R x I) for pod yield indicated that in first year pod yield was more than the second year (Fig 2). In both years, pod yield was more when ground nut was sown as sole crop than all other cropping pattern. In the various intercropping, grown groundnut either with mungbean or guar or sesame had more pod yield than intercropping with sorghum and millets (Fig 2).

Land equivalent ratio (LER) given in Table 4 revealed that all the intercropping was economically feasible by having more than 1.0 LER as compared with sole cropping. Intercropping of groundnut with other legumes (mungbean & guar) seems to be more economical followed by groundnut + sesame intercropping. Lowest LER (1.54) was recorded for both cereals as compared with legumes average (1.82). This study confirmed that groundnut intercropping was more economical than sole cropping of groundnut under dryland condition.

4. DISCUSSION

All the parameters reported here with exception of numbers of plant m^{-2} were significantly affected by cropping systems. The non significant effect of the cropping system on plants m^{-2} could be due to the fact that the expected competition of the intercropping was not yet commence at this stage of the crop growth. In case of yield components, groundnut had significantly less pods $plant^{-1}$, kernel weight, grain yield, biological yield and harvest index when intercropped with cereals (sorghum & millet) as compared with the other members of its own family (mungbean & guar) and sesame. It could be due to the allelopathic effect of cereals (sorghum & millet), depletion of soil nutrients reserve especially N due to the exhaustive nature of these cereals and furthermore the shading effect of these two heavy plants may be the factors limiting yield and yield components of groundnut. Allelopathic affect of sorghum as it contains a number of allelochemicals that are against other crops (Roth et al., 2000; Sene et al., 2000) have been reported. Pearl millet and sorghum were more competitive, and groundnut under these two crops was affected more in term of growth and yield (Gosh, 2004). Competition for nutrients and light in intercropping systems is often interrelated, particularly for legume/non-legume crop combinations. Nambiar et al. (1983) demonstrated that intercrops like pearl millet, maize and sorghum limited the light reaching the groundnut canopy by at least 33% thereby reducing photosynthesis. Reduction in yield, growth and yield attributes in association with pearl millet and sorghum were also reported number of workers (Bandel et al., 1992; Ghosh and Dayal, 1998; Willey and Reddy, 1981; Reddy and Willey, 1981 and Marshal and Willey, 1983).

Trenbath (1976) reported than on low-N soils, the non-legume is often suppressed, but on high-N soils, the vigorous growth of the non-legume usually causes it to dominate over the legume by shading. In our case it is partially true for sesame a non-legume crop where its grain yield in intercropping (data not shown here) increased by 38% and soil N by 32% as compared with its sole cropping, but reverse was true for the cereals. Significant increase in available soil N by cropping systems has been reported by Rathod (2000). He observed that intercropping pigeonpea + cowpea (both legumes) had significantly higher soil N status as compared with pigeonpea + sesame intercropping. Sole millet had less available N than sole pigeonpea (Patil, 2003). Hulihalli (1987) who reported that intercropping of pigeonpea (another legumes) with groundnut significantly reduced the plant height, number of primary branches, leaf area index and total dry matter production of pigeonpea when compared to sole crops. Though cereal fodders depressed the yield of groundnut, an overall benefit was observed when yield of both the crops are considered together (Gosh, 2004).

Land equivalent ratio (LER) of the cropping system presented here revealed that intercropping was more economical than sole growing of groundnut despite the fact that intercropping apparently had reduced pod yield of groundnut in most of the case tested here. The maximum monetary advantage was also recorded for the groundnut/maize intercropping system although monoculture production of cereal fodder or groundnut yielded higher than in the intercropped culture (Gosh, 2004). Significantly higher LER (1.55) under intercropping system of pigeonpea + groundnut when compared to either of the sole crops (1.0) has been reported by Hulihalli (1987). The higher LER of groundnut + guar intercropping is not surprising because of leguminous nature of both crops but the intercropping of groundnut + sesame with the next highest LER is interesting. Hosmath and Patil (1999) reported that sesame intercropping with groundnut, French bean and green gram were found to be best on the basis of yield and profitability. Though cereal fodders depressed the yield of groundnut, an overall benefit was observed when yield of both the crops are considered together (Gosh, 2004) and LER values indicated that groundnut recorded yield advantage in all intercropping systems due to crop complementarities.

5. CONCLUSION

These results based on land equivalent ration (LER) suggests that growing of groundnut in single rows and intercropped with mungbean, guar and sesame under dryland condition could increase crop productivity and soil fertility.

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