World Journal of Agricultural Sciences 3 (2): 243-249, 2007
ISSN 1817-3047

Effect of Incorporation of Leguminous Cover Crops on Yield and Yield Components of Maize

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Abstract: The low and declining productivity of many tropical soils are the major constraints limiting the realization of the improved genetic potential of crops that are now available. The need to take appropriate measures to check this decline in soil productivity is urgent as the rate of deterioration is on the increase and if not checked will have serious implications for future food demands of the increasing human population. The acquisition of enough crop residues for use in the field does not appear very feasible, because they have other attractive alternative uses. In this work forage legumes were planted and allowed to grow for 1 and 2 years before incorporation and the performance of maize was evaluated. Among the legume incorporation treatments, at after one year of growth, *Chamaecrista rotundifolia* gave higher grain yield than the other treatments. After two years of growth, *Centrosema pascuorum* and *Centrosema brasilianum* gave higher grain yields. Grain yield and yield related parameters significantly responded to N fertilizer in the two seasons. However, increased application of N fertilizer tended to increase the stover and ear leaf concentrations of N, K, Ca and Mg. The fallow legumes and food crops may have to be intercropped either simultaneously or in a relay pattern to improve the yield of crops without loosing a season for food crop cultivation.

Key words: Cover crops · incorporation · plant nutrients · N fertilizer · maize

INTRODUCTION

The rapid growth of population in developing countries and the resulting intensive cultivation of agricultural land is causing widespread soil degradation. The low and declining productivity of many tropical soils are the major constraints limiting the realization of the improved genetic potential of crops that is now available [1]. The need to take appropriate measures to check this decline in soil productivity is urgent as the rate of deterioration is on the increase and if not checked will have serious implications for future food demands of the increasing human population.

The shortage and high cost of inorganic fertilizers have limited their use for crop production. There is therefore increased dependence on the use of organic waste such as Farmyard Manure (FYM), compost and crop residues. These are highly valued because of their contribution to soil productivity. This relationship between Soil Organic Matter (SOM) and soil productivity is ascribed to the role of SOM in supplying plant nutrients, enhancing CEC, improving soil aggregation and hence water holding capacity, improving soil pH, supporting soil biological activity [1-3] consequently giving higher crop yield compared to treatments from which crop residue had been removed [4].

In the Northern Guinea Savanna zone of Nigeria, the acquisition of enough crop residues for use in the field does not appear very feasible. This is largely because crop residues have other attractive alternative uses such as livestock feed, fuel wood and fencing materials [2, 5, 6-8].

It is the objectives of this work, to study the performance of maize after one and two years growth of forage legume planted fallow before incorporation.

MATERIALS AND METHODS

The study involved one greenhouse and two field experiments. The three experiments were conducted at the

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Institute for Agricultural Research (IAR), Ahmadu Bello University, Samaru, Zaria (latitude 11º 11'N and longitude 7º 38'E) during 1995 to 1996 cropping seasons. Before this experiment, cotton had been cropped on the field for two years (1991 to 1992 cropping seasons).

Greenhouse experiment: Soil samples were collected at Samaru where the experiment was conducted at 0-30 cm depth. The samples were bulked, air-dried and sieved through a 2 mm sieve. Sub-samples were taken for characterization of some physical and chemical soil properties (particle size distribution, pH, soil organic carbon, exchangeable bases and effective cation exchange capacity). Details of analytical procedures are as described [9].

The shoots of five selected leguminous crops *Centrosema pascuorum* (CP), *Chamaecrista rotundifolia* (CR), *Cajanus cajan* (CC), *Centrosema brasilianum* (CB) and *Stylosanthes hamata* (SH) collected after one year of growth and maize (MZ) stover (collected from a production field). The materials were washed, oven-dried, had them crushed and chopped with cutlass, weighed into pots containing 3 kg sieved soil and thoroughly mixed. The residues were incubated for 2 weeks before maize (var. Oba Super II) was sown. Sub-samples for tissue analysis were ground using a stainless steel Thomas Willey Mill. The details of analytical procedures for N, P, K, Ca and Mg are as described [9]. The growth of the maize plants was terminated at 4 Weeks After Planting (WAP).

The treatments consisted of the shoot of five legume species (CP, CR, CC, CB and SH), MZ Stover and a control (without residue). Each of the residues was applied at two rates of 2.5 t ha^{-1} and 5.0 t ha^{-1}. This showed that there were 13 treatment combinations. The experiment was laid out in a Randomized Complete Block Design (RCBD) and replicated three times. Parameters collected for the grown maize were: plant height (cm) measured 2,3 and 4 weeks after planting; dry matter yield-DMY (g); and nutrient content of maize shoots.

All data collected were subjected to analysis of variance (ANOVA) using SAS package of statistical analysis [10]. The treatment differences were evaluated by the Duncan's New Multiple Range Test (DNMRT).

Field experiment: Two field experiments were carried out: A-One of the experiments was carried in a field where 17 legume species replicated 4 times in a Randomized Complete Block Design (RCBD) were screened for one year, during 1995. Six of the legumes that were promising were selected after one year of growth and incorporated manually by hoeing into ridges 75 cm apart. The six selected legume species were *Pueroria phaseoloides* (PPH), *Chamaecrista rotundifolia* (CR), *Cajanus cajan* (CC), *Centrosema pascuorum* (CP), *Centrosema brasilianum* (CB), *Aeschynomene histrix* (AH) and a natural fallow control. The treatments were replicated 3 times. The field was cropped for one year to maize (var. DMR-LSR-W) in 1996.

Within the main plot (60 m^2) (legume plot and natural fallow control), four N levels (0, 40, 80 and 120 kg N ha^{-1}) as sub-plots (15 m^2) were randomly allocated giving a split-plot design. Nitrogen fertilizer as Urea was applied in two split doses at 3 and 7 WAP. A blanket application of P and K in the forms of Single super phosphate at the rate of 60 kg P_2O_5 ha^{-1} and Muriate of Potash at the rate of 60 kg K_2O ha^{-1} respectively at planting time. The two center rows of each sub-plot made up the net plot, while the two outer rows were considered as discards.

B-In the second experiment, 10 legume species replicated three times in an RCBD were screened for two years, during 1993 and 1994. Five promising legume species selected from the study were incorporated manually into ridges as in the first experiment above. The five selected legume species were *Chamaecrista rotundifalia* (CR), *Centrosema pascuorum* (CP), *Cajanus cajan* (CC), *Centrosema brasilianum* (CB) and *Pueroria phaseoloides* (PPH) and natural fallow control. The treatments were replicated 3 times. The field was cropped for two years to maize (var. DMR-LSR-W) during the 1995 and 1996 seasons. The same plots were maintained for the two seasons. The method of incorporation, plot sizes, N levels and the experimental design are as described for the first experiment above.

Ear leaves at 50% silking were collected for tissue analysis. Details of preparation are as described for greenhouse experiment. These were analysed for N, P and K, as described by Juo [9].

The statistical analysis was the same as for the greenhouse experiment.

RESULTS AND DISCUSSION

Soil properties: Physico-chemical properties of the soils are presented in Table 1. The soils are slightly acid in nature. Values measured in water at 0-15 and 15-30 cm depths were, 5.19 and 5.32 respectively. Organic carbon levels are very low (5.65 and 6.10 g kg^{-1}) in the depths evaluated. Exchangeable bases and effective cation exchange capacity were equally low. However,

Table 1: Physico-chemical properties of the soil used in greenhouse

Properties	Soil depth (cm) 0-15	15-30
pH water	5.19	5.32
pH 0.01M $CaCl_2$	4.81	5.10
Soil organic carbon (g kg^{-1})	6.10	5.65
Exchangeable bases		
Ca (cmol(+) kg^{-1})	2.13	1.83
Mg (cmol(+) kg^{-1})	0.66	0.70
Na (cmol(+) kg^{-1})	0.18	0.19
K (cmol(+) kg^{-1})	0.14	0.13
ECEC (cmol(+) kg^{-1})	3.29	3.61
Particle size analysis		
Sand (g kg^{-1})	650	
Silt (g kg^{-1})	200	
Clay (g kg^{-}-1)	150	
Textural class	Sandy loam	

Table 2: Nutrient content of residue incorporated

Residue	Nutrient contents (g kg^{-1}) N	P	K	Ca	Mg
PPH	19.88	0.50	5.40	3.60	1.70
CR	24.64	2.00	5.40	2.10	1.70
CB	15.40	1.50	4.59	2.60	1.70
CC	21.00	0.50	5.13	2.60	1.18
CP	26.88	1.50	7.56	5.70	1.98
SH	16.58	0.70	6.27	3.26	1.45
MZ	12.45	1.25	9.45	0.92	1.25

Note: PPH = *Pueroria phaseoloides*, CR = *Chamaecrista rotundifolia*, CB = *Centrosema brasilianum*, CC = *Cajanus cajan*, CP = *Centrosema pascuorum*, SH = *Stylosanthes hamata*, MZ = *Zea mays*

Table 3: Effect of legume incorporation on maize plant height and dry matter yield in the greenhouse

Treatment	Plant height (cm) 2 WAP	3 WAP	4 WAP	DMY (g) 4 WAP
Legume SPP				
NL_0	3.13f	6.60d	7.93d	0.76c
CR_1†	4.44b-f	7.83bcd	10.40abc	0.98abc
CB_1	4.97bc	7.53bcd	9.53a-b	0.96abc
SH_1	4.00b-f	6.97cd	8.60bcd	1.03abc
CC_1	3.53d-f	7.67bcd	9.97a-d	1.04abc
CP_1	3.87c-f	7.23cd	9.77a-f	1.13abc
MZ_1	4.57b-e	8.03bcd	10.27abc	1.10abc
CR_2‡	7.10a	8.77ab	11.27abc	1.37a
CB_2	4.70bcd	8.03bcd	9.90a-d	0.99abc
SH_2	4.30b-f	7.53bcd	9.73a-d	0.93abc
CC_2	3.40ef	8.17bc	10.07a-d	1.27ab
CP_2	5.03bc	7.93bcd	9.77a-d	0.99abc
MZ_2	5.20b	9.87a	10.87ab	1.27abc
S.E±	0.38	0.45	0.68	0.14

Means followed by the same letter(s) within a treatment group are not significantly different at 5% level of significance using DNMRT, Note: NL = No legume, 1† = 2.5 t ha^{-1}, 2‡ = 5.0 t ha^{-1} and 0 = No residue, CR = *Chamaecrista rotundifolia*, CB = *Centrosema brasilianum*, CC = *Cajanus cajan*, CP = *Centrosema pascuorum*, SH = *Stylosanthes hamata*, MZ = *Zea mays*

exchangeable Ca (2.13 and 1.83 cmol kg^{-1}) dominated the exchange complex at 0-15 and 15-30 cm respectively. These characteristics are typical of savanna soils of Nigeria [2]. The soils were sandy loam in texture.

Greenhouse experiment:

Nutrient composition of incorporated residues: The nutrient contents of residues incorporated are shown in Table 2. The total N content of CP is highest (26.88 g kg^{-1}), followed by the other leguminous residues (Table 2). The maize residue has the lowest value (12.45 g kg^{-1}). According to Balasubramanian and Nnadi [8] crop residues of leguminous plants are richer in all nutrients than cereal crop residues. Leguminous crops are known to have a smaller C: N ratio than cereal crops. Giller and Wilson [11] stated that, legume residues are particularly useful as organic manures due to their large content of N and because this N is more likely to become readily available for uptake by other plants than N in many crop residues. However, the MZ residues had higher contents of K (9.45 g kg^{-1}) than all leguminous residues.

Effect of legume incorporation on maize plant height: Generally, plant height increased over the control under all the treatments during the 2, 3 and 4 weeks after planting periods (Table 3). This may be attributed to residues when incorporated, upon decomposition will release nutrients for crop use. In addition organic matter will improve soil physical and chemical properties which lead to higher plant height. Among the legume treatments differences in plant height were observed. The CR_2 treatment gave taller plants than most other treatments. This effect is probably due to lower C: N ratio which allows a faster release of nutrients (N) than other legumes (e.g. CP which had a higher N value) (Table 2). Giller and Wilson [11] reported that, legume residues commonly have C:N ratios less than 30 : 1 and therefore tend to release N and decompose rapidly.

Comparing the rates of residue application the 5.0 t ha^{-1} treatments gave taller plants than the 2.5 t ha^{-1} treatments.

Effect of legume incorporation on maize Dry Matter Yield (DMY): Organic matter will enhance soil CEC, improving soil aggregation; hence, improved water retention and supporting biological activity. Haque [12] and William [13] reported DMY increase when legumes were incorporated into the soil.

Table 4: Effect of legume incorporation on nutrient content of maize in the greenhouse

	Nutrient contents (g kg^{-1})				
	N	P	K	Mg	Ca
NL_O	2.48d	2.08d	9.61e	1.18bc	1.83b
CR_1	3.09bcd	2.63bcd	14.49a-d	1.55ab	2.60ab
CB_1	2.72cd	2.42cd	13.25b-e	1.33abc	2.73ab
SH_1	2.77bcd	2.00d	14.45a-d	1.33abc	2.37ab
CC_1	3.36a-b	2.17d	12.59cde	1.33abc	1.83b
CP_1	3.65ab	3.00abc	13.35b-e	1.57ab	2.73ab
MZ_1	2.57cd	2.67bcd	15.72abc	1.40abc	2.17ab
CR_2	3.22a-d	3.63a	17.14ab	1.69a	3.27ab
CB_2	3.41abc	3.04abc	16.80abc	1.65a	3.13ab
SH_2	3.08bcd	2.54bcd	17.00abc	1.61ab	3.20ab
CC_2	2.88bcd	3.13abc	17.16ab	1.55ab	3.07ab
CP_2	4.05a	3.71a	18.05a	1.74a	3.40a
MZ_2	3.15bcd	3.29ab	17.39ab	1.59ab	3.10ab
S.E±	0.27	0.25	1.34	0.13	0.44

Means followed by the same letter(s) within a treatment group are not significantly different at 5% level of significance using DNMRT, Note: NL = No legume, 1† = 2.5 t ha^{-1}, 2‡ = 5.0 t ha^{-1} and 0 = No residue

Table 5: Effect of legume incorporation after one year of growth and N fertilizer on maize grain yield

Treatment	Grain yield (t ha^{-1})
Legume SPP (L)	
PPH	0.67c
CR	1.08a
CB	0.65c
CC	0.70c
CP	0.67c
AH	0.92b
Control	0.47d
S.E±	0.04
N rates (N)	
0	0.26d
40	0.67c
80	0.96b
120	1.05a
S.E±	0.03
Interactions	
L×N	**

Means followed by the same letter(s) within a treatment group are not significantly different at 5% level of significance using DNMRT, Note: PPH = *Pueroria phaseoloides*, CR = *Chamaecrista rotundifolia*, CB = *Centrosema brasilianum*, CC = *Cajanus cajan*, CP = *Centrosema pascuorum*, AH = *Aeschynomene histrix*, L×N = Legume interaction with Nitrogen, ** = Significant at 1%, L = Legume, N = N fertilizer rate

There were yield differences among the different types of legumes (Table 3). At 2.5 t ha^{-1} CP gave the highest DMY, while at 5.0 t ha^{-1} CR gave the highest yield. The slight differences among residues are likely related to the quality of the materials incorporated. According to Henzell and Vallis [14] a predictable consequence of the variable N concentration in different legume residue is that they will contribute varying amounts of N to the soil and likewise to the following crop, most of the differences between residues can be attributed to their N percentages.

There were no yield differences between the rates of application of residues. However, CR_2 and CC_2 gave significant differences than the control treatment. CR_2 gave the highest value, which was not significantly different from CC_2.

Effect of legume incorporation on nutrient content of maize shoot: The effect of legume incorporation on maize shoot nutrient concentrations are shown in Table 4. The values of these nutrients were consistently higher in plants that received the residues than the control, though the differences were mostly not significant. Lal [15] and Bin [16] reported that, incorporation of organic matter can enhance the nutrient balance by serving as a nutrient reservoir in the soil, supplying N, P and other nutrients. But for why the differences were not significantly different could be associated to dilution effect. Dahiya [17] and Singh [18] had made similar observations, there were decreases in Ca, Mg, Mn and Fe concentrations in oat shoots with increasing levels of manure and attributed it to dilution effect.

Between the legumes, there were slight differences in the contents of these nutrients. This could be due to the differences in the nutrient contents of the residues applied. The elemental content of the tissue at 5.0 t ha^{-1} is higher than at 2.5 t ha^{-1}. It is believed that the materials incorporated released more nutrients for crop uptake and utilization. Henzell and Vallis [14] make a similar statement, that a predictable consequence of the variable N concentration of different legume residues is that they will contribute varying amounts of N to the soil and likewise to the crops following. Most of the differences between residues can be attributed to their N percentages.

FIELD STUDY

Effect of legume incorporation after one year of growth and N fertilizer on maize grain yield: The effect of legume incorporation after one year of growth and N fertilization on maize grain yield is shown in Table 5. The generally low maize grain yield could be attributed to late planting, maize variety (DMR-LSR-W) and effect of drought spells. Grain yield was significantly higher in CR than other treatments. Between PPH, CB, CC and CP

Table 6: Effect of legume incorporation after two years of growth and N fertilizer on maize grain and stover yields

	Grain yield (t ha^{-1})			Stover yield (t ha^{-1})		
Treatment	1995	1996	Mean	1995	1996	Mean
Legume SPP (L)						
PPH	0.97e	1.53bc	1.25c	3.59a	3.98a	3.78a
CR	1.28d	1.93a	1.60b	4.03a	4.26a	4.15a
CB	1.66b	2.07a	1.86a	4.12a	4.18a	4.15a
CC	1.56c	1.75ab	1.65b	3.55a	4.07a	3.81a
CP	1.87a	2.01a	1.94a	4.02a	4.02a	4.02a
Control	0.84f	1.37d	1.11c	3.60a	2.37b	2.98b
S.E±	0.02	0.12	0.06	0.22	0.13	0.13
N rates (N)						
0	0.56d	0.86c	0.68d	2.33b	2.48d	2.41d
40	1.37c	1.65b	1.51c	4.06a	3.79c	3.93c
80	1.68b	2.22a	1.95b	4.35a	4.20b	4.27b
120	1.83a	2.44a	2.14a	4.55a	4.78a	4.66a
S.E±	0.02	0.10	0.05	0.18	0.12	0.11
Interactions						
L×N	**	NS	**	NS	NS	NS

Means followed by the same letter(s) within a treatment group are not significantly different at 5% level of significance using DNMRT

Note: L = Legume; NS = Not significant; N = N fertilizer rate (kg ha^{-1}); ** = Significant at 1%, PPH = *Pueroria phaseoloides*, CR = *Chamaecrista rotundifolia*, CB = *Centrosema brasilianum*, CC = *Cajanus cajan*, CP = *Centrosema pascuorum*

differences were not significant. The differences recorded among legumes could be attributed to their quality and quantity of biomass produced [14, 19]. In general, all legume treatments gave significantly higher grain yield increase of between 0.18-0.61 t ha^{-1} (38.3-129.8%) over the control. Harian and Van Noordwijk [20] reported that maize yield was more than doubled by incorporation of three month old Mucuna and Crotolaria grown in alluvial soil on the Island of Java, Indonesia. The field study result confirms what was obtained in the greenhouse with CR giving the highest DMY.

Increasing rates of N application significantly increased the grain yield. Cereal crops in the study area demand high amounts of N for improved yield since the soils are inherently low in soil N. However, yield values obtained in this study are low (<1.05 t ha^{-1}) due to effects of late planting and nature of maize variety. Higher doses of N fertilizers have been reported to increase grain yield [21-23]. The interaction between the legume residues and the N fertilizer was highly significant. Charreau [24] has reported that the combine effect of organic matter and mineral fertilizers applications achieved higher yields with the same amount of mineral nutrients when these are received in combine form (mineral and organic) than when mineral fertilizer is applied alone.

Effect of legume incorporation after two years of growth and N fertilizer on maize grain and stover and some yield components: Legume incorporation and N fertilizer significantly affected maize grain yield in the two seasons (1995 and 1996 seasons) (Table 6). Grain yield was significantly higher with the incorporation of legumes than the control for the two seasons. Yield increases over the control upon incorporation were 0.13 to 1.03 t ha^{-1} (15.3 to 122.6%) for 1995 season and 0.16 to 1.30 t ha^{-1} (11.7% to 51.1%) for the 1996 season. The yield increase observed in the 1996 season clearly demonstrated residual effect of these legumes. With the pooled data, legume incorporation gave 0.11 to 0.83 t ha^{-1} (12.6-74.8%) yield increase over the control (Table 6). Increase in grain yield with the incorporation of forage legumes had been reported by several reseachers [19, 20, 25-27].

Stover yield was not significantly affected by treatments in 1995 season (Table 6). In 1996 and pooled data analysis, incorporation treatments significantly gave stover yields that were significantly higher than the control treatment. Probably the amount of nutrients released to the crop by the legume residues incorporated was not high enough to create a significant difference on the stover yield in 1995 season. But, in 1996season as a result of nutrient depletion due to the harvest (grains and stover) of 1995, the legume residues were able to show a significant difference on the stover yield.

The application of N fertilizer gave a similar effect for the two seasons, 1995 and 1996 on grain yield (Table 6) as discussed above, under the effect of legume incorporation after one year of growth. This further confirms that increasing N application significantly increased the grain yield even after two years of growth before incorporation. However, in 1996 season there was no significant difference between the 80 and 120 kg N ha^{-1} rates. The application of N at higher rates equally increased the stover yield significantly, except 1995season, where there was no significant difference between the 80 and 120 kg N ha^{-1} rates.

The interaction between the legume residues and the N fertilizer in 1995 and pooled data was highly significant on the grain yield. This also agreed with the results of, effect of legume incorporation after one year of growth discussed above. However, the interaction was not significant in 1996 season and on the stover yield. The reasons already advanced above could be the reasons.

Table 7: Effect of legume incorporation after two years of growth and N fertilizer on nutrient content of maize ear leaf in 1996 season

	Nutrient content		
Treatment	N	P	K
Legume SPP (L)			
PPH	19.51c	1.95c	10.56a
CR	23.25b	2.27a	9.87ab
CB	21.25b	2.09ab	9.22b
CC	23.61a	2.17ab	9.37b
CP	19.19c	1.66c	9.38b
Control	20.44bc	2.23a	9.72a
S.E±	0.50	0.08	0.33
N rates (N)			
0	13.79d	1.66d	8.70c
40	18.88c	1.94c	9.43ab
80	24.39b	2.21b	9.93ab
120	27.93a	2.43a	10.69a
S.E±	0.41	0.06	0.27
Interactions			
LxN	NS	NS	**

Means followed by the same letter(s) within a treatment group are not significantly different at 5% level of significance using DNMRT, Note: L = Legume; N = N fertilizer rate (kg ha^{-1}); NS = Not significant** = Significant at 1%, PPH = *Pueroria phaseoloides*, CR = *Chamaecrista rotundifolia,* CB = *Centrosema brasilianum*, CC = *Cajanus cajan*, CP = *Centrosema pascuorum*

Effect of legume incorporation after two years of growth and N fertilizer on nutrient concentration of maize: Maize ear leaf concentrations of N, P and K did not show any clear trend in 1996 (Table 7). [28] reported similar inconsistencies in nutrient concentrations in their study. However, the N content of CC treatment was significantly higher than the control.

The N, P and K increased significantly with increasing rates of N fertilizer. These increases are expected as N, P, K, fertilizers were applied. This will have enhanced good growth especially roots, leading to adequate absorption of these nutrients from the soil. Lal [5] reported increases in ear leaf N and K concentration with N fertilizer application.

CONCLUSIONS

- Incorporating some legume species in to the soil even after one or two years of growth considerably reduce the amount of N fertilizer required by a cereal crop.
- Legume species when incorporated into the soil could have strong residual effect. Grain yield increases in the second year of cropping range from 0.14-0.65 t ha^{-1} (7.49-50.78%) higher than the first year.
- Among the legume treatments and after one year growth before incorporation, CR gave higher grain yield than the other treatments; while at two years growth before incorporation CP and CB gave higher mean grain yields over both seasons (1995 and 1996) than the other treatments.
- It may be more beneficial to incorporate some legume species such as CP and CB after two years of growth, while other legume species can be incorporated after one year of growth, such as CR.
- Grain yield and yield related parameters significantly responded to N fertilizer in the two seasons. However, increased application of N fertilizer tended to increase the stover and ear leaf concentrations of N, P and K.
- The adoption of the technology might be hindered by the fact that, these legumes do not have immediate food grain benefit like the grain legumes (i.e. cowpea, soyabean and Lablab). The fallow legumes and food crops have to be intercropped either simultaneously or in a relay pattern to improve the yield of the crop without loosing a season for food crop cultivation.

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