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thesis entitled

EFFECT OF ASSOCIATED CULTURE ON GRAIN YIELD, PERCENT PROTEIN AND PERCENT OIL OF MAIZE, DRY BEANS AND SOYABEANS.

presented by

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has been accepted towards fulfillment
of the requirements for

MASTER OF SCIENCE degree in AGRONOMY

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Date May 12, 1980

EFFECT OF ASSOCIATED CULTURE ON GRAIN YIELD, PERCENT PROTEIN AND PERCENT OIL OF MAIZE, DRY BEANS AND SOYABEANS

By

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A THESIS

Submitted to
Michigan State University
in partial fulfillment of the requirements
for the degree of

MASTER OF SCIENCE

Department of Crop and Soil Sciences

1980

ABSTRACT

EFFECT OF ASSOCIATED CULTURE ON GRAIN YIELD, PERCENT PROTEIN AND PERCENT OIL OF MAIZE, DRY BEANS AND SOYABEANS

By

M. Emil T. Mmbaga

Two associated culture experiments (maize in association with either dry beans or soyabeans) of 21 treatment combinations each, were conducted in the field on the Michigan State University crops farm at East Lansing, Michigan 1978. In each experiment, two maize planting densities (22,500 and 45,000 plants/ha), three row spacings (75, 100, and 130 cm), three legume configurations (17 or 25, 38, and 50 cm from maize rows), two monoculture maize, pure culture dry beans (200,000 plants/ha) and pure stand soyabeans (300,000 plants/ha) were arranged in a randomized complete block design.

Maize grain yields of five treatment combinations in maize-beans and in only one treatment in maize-soyabean association were not significantly different from monoculture maize yield. Maize at the high density with rows 100 cm apart and interplanted with double rows of soyabean 38 cm from maize rows gave significantly higher percent protein of maize than monoculture maize. Percent oil of maize

grown in associated culture was not significantly different from maize grown in pure culture (except a single treatment combination with higher oil content than monoculture in the maize-soyabean association).

Beans and soyabeans were 45 to 66% and 38 to 68% lower in seed yield, respectively, than their pure culture yields. Percent protein in bean seed in associated culture was non-significant as compared to monoculture while percent protein of soyabean seed was significantly higher in associated culture than in monoculture. However, percent oil of soyabean seed in associated culture was significantly lower than in monoculture soyabeans.

Land equivalent ratio (LER) values of maize-beans, and maize-soyabeans were up to 1.34 and 1.14 higher, respectively, than monoculture value. Combined yields of maize and beans, and maize-soyabeans were up to 55% and 48% higher, respectively, than the component crops grown separately.

Gross revenue returns of associated culture crops were up to 14% and 26% higher than pure culture crops in maize associated with beans and soyabeans, respectively. As high as 1165 and 1082 kg/ha total protein yields were achieved from maize-beans and maize-soyabean association, respectively. The protein was adequate to feed up to 49 and 46 men, respectively, for one year as compared with pure culture farming where protein was sufficient to feed only 38 men for the same period.

It was noted that higher (than monoculture) values of LER, combined yield, protein and economic returns were constantly obtained from both experiments when maize at the high density was spaced 75 cm apart and interplanted with a single row of beans or soyabeans. Furthermore, it was suggested that 130 cm row width was more convenient in the developing countries than other spacings in conducting cultural operations such as hand weeding, spraying, fertilizer application and harvesting of the minor crops. On the other hand, 75 cm row width had merits over the other spacings in that it suppressed weeds earlier in the growing season but was deficient in providing opportunities for other cultural practices.

To my wonderful and beloved parents, who through their moral support, constant encouragement and love have always been my inspiration and foundation for my success and achievements throughout my career.

To Mary A. Macha, my friend, for her patience, kindness, constant correspondence, care and love throughout my stay in the United States of America.

To Enea and Roseline, my children, whom I love and promise to do the best I can for their daily life.

ACKNOWLEDGEMENTS

The author sincerely expresses his appreciation to his major professor, Dr. M. Wayne Adams for the enthusiasm, kindness, moral support, knowledge, experience, encouragements, and patient guidance throughout the course of this study and for his constructive criticism in the preparation of this manuscript.

Gratitude is also expressed to Drs. George L. Hosfield, Alfred W. Saettler and John C. Shickluna for serving as guidance committee members and for their valuable contributions and substantive discussions throughout this study.

He is also grateful to Drs. M. Wayne Adams, George L. Hosfield, Pericles Markakis and Mark A. Uebersax for allowing him to use their facilities which provided the framework for his success.

Special appreciation is extended to Drs. Lynn S. Robertson and Alan R. Putnam for their suggestions and to Mr. D. Michael Williams of Dickey-john corporation for his unlimited effort to calibrate the Grain Analysis Computer for the analysis of protein and oil content of his samples.

Special acknowledgements are extended to Mr. N. Georges Agbo for his assistance in the laboratory and to

Mr. Douglas C. Carter for his suggestion and assistance in setting up the experiment.

Sincere thanks and appreciation are also extended to all his brothers, sisters, relatives and friends particularly those at Ilonga Research Station for their continuous care and correspondence throughout his study.

Finally, the author deeply appreciates the scholarship from the government of the United Republic of Tanzania and he is also indebted to the International Institute of Tropical Agriculture for their financial support.

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INTRODUCTION

Associated culture is a traditional practice of subsistence farmers in many developing countries. Maize-bean association is one of the most important agricultural systems used by small farmers in the tropics. Associated culture consists of the growing of two or more different crops simultaneously in alternate rows in the same field within a common growing season. It differs from mixed cropping in that two or more crops are grown simultaneously within the rows of a major crop or in an unorganized spatial arrangement. In other words, intercropping (associated culture) is an inter-row whereas mixed cropping is an intra-row planting of two or more different species simultaneously in the same field in a single season. Each system experiences interspecific competition for limiting or potentially limiting resources, which may result in reduction in yield of one or both crops as compared with monoculture, although the combined yield of associated culture is sometimes higher than either of the component crops in pure stand.

Generally, intercropping or associated culture is characterized by high plant species diversity, closed cycling of soil nutrients and reduced incidence of diseases and pests. Associated culture often provides better weed and erosion control, low but stable yields and provides an intensive exploitation of limited land resources (32). It is also characterized by interspecific competition between two crop species as opposed to monoculture in which there is only intraspecific competition within a single crop species (43). Competition between the major and minor (interplanted) crops is likely to reduce the yield of the former to an amount that depends on the nutrient requirements and growth habits of the latter (24). Maize yield compensation from the minor or interplanted crops will depend partly on maize and interplanted crop growth duration and partly on the growth habits of the major crop (24). Associated culture provides higher combined yield, protein and economic returns.

Surplus labour availability, limited land and capital, greatly stimulated intercropping as a production system in subtropical and tropical countries where small farmers are provided with their daily food requirements through an intensive and efficient use of available resources. Associated culture of legumes and non-legumes or cereal species have been practiced for centuries as a means of maintaining soil productivity. In poor soils, non-legumes perform better in associated culture than when in sole crop because they utilize nitrogenous compounds synthesized and transferred by the legumes either from a previous or within the same crop season (2).

The types and choices of crops grown in intercropping systems depend on personal tastes, traditions, environmental factors and economic factors. However, intercropping a staple crop such as maize with a minor legume crop like beans, cowpeas, groundnuts, mung beans and pigeon peas is widely employed in tropical areas to provide balanced nutritional supply of carbohydrates and protein.

Over 85% of the beans in Tanzania are produced in association with both cash and food crop intercrop particularly young coffee plantations, maize, sorghum, sweet potatoes, cassava and banana. Beans are served with rice, different forms of banana, maize and cassava dishes. They are also cooked either as green or dry beans together with potatoes, maize, cassava and yams.

Bean leaves are also served as vegetables. An average family in Rwanda, Uganda and Tanzania consumes beans at least four days per week. Indeed, beans will continue to be the only cheap source of protein in developing countries as a result of the rise in meat price.

Unfortunately, intercropping is unamenable to mechanization and thus hand labour is needed for almost all field operations such as planting, weeding and harvesting. Associated culture could also be a problem if the component crops have different requirements for herbicide, fertilizer and pesticide. Nonetheless, intercropping probably will continue to be the major production system in the developing countries possibly due to low income, land shortage (as a result of increased population) and increase in prices of agricultural inputs.

The objective of this study was to determine whether growing maize with beans or soyabeans will affect total grain yield, crude protein and crude oil of the component crops in associated culture. I therefore, hypothesized that:

(1) On an equivalent land basis, combined yield of the component crops in associated culture will be higher than monoculture component crops due to more efficient utilization of environmental factors.

(2) Total crude protein will be higher in maize grown in associated culture than in monoculture as a result of amino acids excreted from legume plants which are then available for use by maize and eventually for protein synthesis.

(3) Maize oil content will remain unchanged probably because maize has low oil content and consequently, maize plant uses less stored energy for oil synthesis.

(4) Soyabean crude oil content in associated culture will be lower than in monoculture soyabean while protein content will remain unchanged because more stored energy is used for oil synthesis and relatively smaller amount of calories is used for protein synthesis (46), consequently, under a low

energy supply in associated culture, oil content will be more affected than protein content.

LITERATURE REVIEW

Legumes in associated culture quickly establish a canopy which intercepts light not intercepted by the main crop, suppresses weeds, reduces run off and evaporation. As a result, water storage for use by component crops is increased. In addition to protecting soil from erosion, the legume canopy also modifies soil temperature and improves soil fertility by adding organic matter and nitrogen to the soil through root, stem and leaf decomposition and fixation of atmospheric nitrogen, respectively. Intercropping also minimizes the effects of a complete crop failure due to environmental factors. One component crop compensates should the other crop fail to grow as a result of insect or disease damage. Associated culture provides flexibility for markets and prices.

Crop yields of maize-beans, and dwarf sorghum-bean association were up to 38% and 55% higher, respectively than could be achieved by growing the component crops separately due to a greater utilization of environmental resources, different rooting depths and their different growth cycles (5, 75, 101). The largest yield increases were achieved at the high maize and bean planting densities (20, 101). Maize has a higher relative competitive ability than beans probably due to the shading effect which the maize imposes on the beans (101). This relative competitive ability increases with increased plant population.

Experiments conducted in Kabete, Kenya showed that maize-bean association gave an apparent yield advantage over pure stands, due to increased population pressure in the mixtures (27). Sowing beans two weeks before maize gave the best balance of competition and the highest yield (29), showing that in some circumstances, this change in relative competitive ability could be beneficial. On the other hand, beans suffered strong competition from the maize, principally when planted simultaneously with the higher maize populations and maize yield was not affected by the bean (68, 79); or in some cases, a modest reduction in yield was offset by production from the minor crop (1, 21).

Climbing (indeterminate) beans gave the poorest yields when planted simultaneously with maize because an appropriate climbing support was lacking at a critical stage in bean plant development (79). Bean-maize systems have provided a source of income and a balanced diet for the farm family (32) in Latin America for centuries. In an economic analysis, Hart (44) found that when beans, corn, and manioc were planted at the same time, yield and economic returns were 37% and 54% higher, respectively, in the polyculture than in the monocropping system.

Intercropping of maize with soyabeans in Morogoro, Tanzania, increased maize yield by 34% and decreased soyabean yield by 51% as compared to their yields under sole crop conditions (63, 85). However, soyabean yield under short maize was 17% higher than under tall maize (91). Planting legumes in alternating single rows gave greater returns than other intercropping patterns (57) although other researchers (78, 85) report slightly higher yields of maize and soyabeans, and of sorghum and soyabeans when planted in alternating double or triple rather than single rows.

Intercropping of soyabeans and maize in alternate rows in a 1:1 ratio gave higher yields than the pure stands of maize or soyabean at all levels of nitrogen fertilization. Yield of intercropped soyabeans was depressed particularly at high nitrogen rates, possibly due to the shading effect of maize (4, 78). Soyabean at 50% basic density intercropped with 100% maize and vice versa did not significantly reduce maize yield (94% of sole crop maize) and soyabean yield was 74% of soyabeans in pure stand. When both maize and soyabeans were intercropped at 100% basic densities each, individual crop yields were significantly reduced, that is, 74% of maize and 63% of soyabean monoculture (37).

Pigeon peas and cowpeas had greater adverse effect on grain yield of sorghum than beans, but with maize, beans and cowpeas had a more adverse effect on grain yield than pigeon peas, although Dalal (19) found a significant reduction of grain yield of maize but not of pigeon peas. Although intercropping maize with either beans or cowpeas decreased total grain yield of the component crops, intercropping sorghum with pigeon peas increased total grain yield (24). In Ghana (64), groundnut yields in mixed cropping were one-third to one-half the yields obtained in pure culture, but maize yield was not reduced to the same extent. Inter-row cropping appeared to be the best in terms of yield, cash return, fertilzer application, spraying and weeding (64). At constant plant populations of maize and groundnuts, varying row arrangements had little effect on yields (52) and yields of each species in polyculture were reduced in comparison to pure stand (21, 90). Cowpeas and greengram (1) tended to compete with maize during the late cropping season resulting in suppressed legume yield by maize shade but maize yield was not seriously affected. High yields of maize were maintained during the four growing seasons in Nigeria (1) in both the fertilized control plots and those interplanted with different legumes without fertilizers, whereas, the yield of maize in plots with neither legume nor fertilizer was reduced to half the yield of the first maize crop.

The efficiency of intercropping is estimated in several ways but the most commonly used is land equivalent ratio (LER) which specifies the size of an area of land which would be required by sole crops to provide the same yield as that given by the components being grown together on unit area. LER should be calculated by using the optimum pure culture yield for each component in order to ascertain whether or not the farmer will be technically better off with a mixture or monoculture (47):

$$\text{LER} = \frac{\text{Yield of maize in associated culture}}{\text{Yield of maize in monoculture}} + \frac{\text{Yield of beans in associated culture}}{\text{Yield of beans in monoculture}}$$

LER greater than 1 indicates a gain in grain (maize plus beans) production in associated culture. A wide variety of intercrop combinations exist and LER of up to 2.0 have been reported in several cases (9). However, at very wide spacing the LER will be close to 1. Work done at the Faculty of Agriculture, Morogoro, Tanzania, obtained LER in millet-soyabean, and sorghum-soyabean intercropping ranging from 1.04 to 1.44 compared to 1.0 for pure stands (54). The data indicated that more than one hectare of sole crop was required to produce the yield of one hectare of intercropped crop components. Francis (29) reported LER of greater than unity and as high as 1.88 for combinations of dwarf and normal maize and bush and climbing bean types. The LER was lowest when maize was planted before the beans and when climbing bean types were used.

Surprisingly, IRRI (53) found that LER values tended to be closer to unity under poor climatic and management conditions although polyculture is supposed to ameliorate the effects of adverse conditions. They also found that when one crop was heavily attacked by disease, the LER was reduced but never fell below unity with mung bean - maize and maize - rice combinations on farms.

Intercropping of maize with dry beans in Colombia (17), maize with groundnut in Taiwan (17), maize with soyabean in Egypt (36), India (85) and Indonesia (89), provided LER values of 1.4, 1.5, 1.22, to 1.31, 1.2 to 1.4 and 1.2 to 1.3, respectively. The LERs obtained from intercropped maize plus soyabean (53) or maize plus green gram (57) were always greater than 1.0, being as high as 1.6 depending upon the amount of N supplied to the soil. Garcia et al. (37) found that intercropping maize at 100% basic density and soyabean at 50% basic density produced more foodstuff, highest LER (1.41) and possibly better net income than monoculture.

Effects of an intercrop are somewhat self-compensating, a drop in population or poor growth of one crop allows another to yield more, thus, exemplifying one of the safety features (8). Maize and sorghum have higher temperature requirements for optimum growth than beans and respond better to high light intensities (17). These species remove carbon dioxide from the air more efficiently and thus have quite different environmental demands from other food crops like beans, potatoes or small grains. Thus, at any time, maize will make maximum use of the environment before beans. This allows for better soil use since plants with varying environmental demands can be crowded together more compatibly than can plants which respond identically and, thus, compete with each other (17). Light supply exceeds the requirements at the beginning of the growing season and becomes scarce at the later part of the season leading to light competition. Likewise, nutrients and soil moisture requirements are in peaks during tillering and panicle initiation of cereals which may not meet the high demands of component crops (10).

Generally, two plants do not compete with each other as long as resources (water, nutrients, light, CO_2, temperature) are in excess of the needs of the crop components. When the immediate supply of a single necessary factor falls below the combined demands of the plants, competition begins (41) and yields of component crops in intercropping may be low due to competition for nutrients, water, light, space, oxygen and carbon dioxide (24, 93). Thus, a combination of intra-specific and inter-specific competition will affect total dry matter production, distribution in each component crop and economic yield of grain of associated culture (33).

Intercropping is more popular due to built-in balanced nutritional supply of energy and protein, profit and resources maximization, efficient water utilization, inexpensive weed control, minimization of agricultural risks, broad utilization of hand labour and improvement of soil fertility (2, 5, 24, 77). Willey et al. (101) suggested that yield advantage of the mixtures may be due to more efficient utilization of light by the combination of a tall maize with a short bean. However, Osiru et al. (75) obtained larger advantages for mixtures of dwarf sorghum and beans and concluded that different rooting patterns might have provided a more efficient exploitation of the soil resources. Khristozov (62) in Bulgaria, found that soyabean inhibited the growth of maize stems and ear development but did not affect the number of cobs and leaves and maize inhibited soyabean growth by shading. Similarly, Dzhumalieva (22) noted that soyabean stimulated the development of sorghum root system, whereas sorghum suppressed both root and nodule development in soyabeans. Soyabean intercropped with wheat branched very little until the wheat was harvested. Emergence of branches depended mainly on the content of available carbohydrate in the plants while N content did not seem to be a limiting factor (74).

Associated culture is characterized by reduced pest populations compared to monocultures of the same crops due to more natural enemies, microclimatic gradients (mainly shading) and chemical interaction (7). Grain sorghum has been shown to furnish a suitable habitat for the build up of cotton bollworm predators (Lady beetles, green lacewings, hooded beetles and spiders) which provide a natural and inexpensive alternative to chemical insect control (17). When four rows of sorghum were planted for every twelve rows of cotton, large numbers of beneficial insects were found in the cotton and they provided even better insect control than pesticides as the latter killed both the predators as well as the bollworms (17). Brown (12) and Francis et al. (30) reported a lower incidence of fall army worms on maize associated with soyabeans and maize-bean mixture planted six days before maize, respectively, than on pure stand maize. Likewise, Sastrawinata (82) found that maize-groundnut and maize-soyabean polycultures reduced the number of corn borer egg masses, larvae and pupae on maize plants at both 20,000 and 40,000 maize plants per hectare.

Willey et al. (101), however, noted that an attack of gall midges on the bean pods seemed to be worse in polyculture plots because the mixture provided a more humid and shady environment. IITA (49) and IRRI (50, 51) reported increased incidence of soyabean and mung bean rust when intercropped with maize than when planted in monoculture. On the other hand, IITA (49) and Soria et al. (87) reported that the incidence of rosette in groundnuts and rust in beans, respectively, were higher in pure stand than in associated culture with maize as the main crop acted as a natural barrier impeding free dissemination of the pathogen. Kavumbo (59) suggested that the stability of intercropping results from their ability to maintain yields despite pest and disease attack due to growing of mixtures that have a "spare capacity" or are able to compensate for damage caused by pests. Many photophilic pests (require abundant light) avoid short crops when they are shaded by taller crops because they cannot spread so easily through intercropped fields, which provided a less favourable habitat for some of the major pests than when the crops are grown separately (38, 71). Changes in colour, texture and shape of the crop canopy in associated culture may vary the optical stimuli available to these insects and decrease their colonization efficiency. There may also be some adverse chemical stimuli which come from the respective companion plants (7).

Environment influences maize grain chemical composition and a similar environmental influence on the protein content of chick peas was reported in Russia (16). Cultural practices also have an influence on chemical composition of seed. Soyabeans develop a higher oil content if planted early in the season and progressively decreases with later planting dates. Protein content of maize ranges from 7.44 to 12.88% within hybrids with an average of 8.9% protein and 3.9% oil. Dry beans contain an average of 22.3% crude protein and 1.7% oil, while soyabean average protein is about 38% and average oil content is about 18% (16, 25). It can be noted that soyabeans are relatively high in oil and protein and relatively low in carbohydrates. Corn, on the other hand, is high in carbohydrates and low in oil and protein. About 6% of the total energy stored by the maize plant is used for oil and protein synthesis while about 17% of the total energy stored by the soyabean plant is used for oil and about 12% for protein synthesis (46).

Howell (46) found that fats and oils contain 2 1/3 times as much energy per pound as do carbohydrates and proteins contain 1 1/3 times as much (4,300; 2,560; 1,860 Kcal/lb, fat, protein and carbohydrates, respectively). It is thus obvious that soyabeans concentrate more of its fixed amount of energy into high-energy oil and protein units, consequently, making fewer pounds of seed than maize. In making one pound of oil a plant uses nearly five pounds of carbohydrates (2.7 lb of the carbohydrates are compressed into one pound of oil and 2.3 pounds is burned in the process of building the higher-energy oil). The synthesis of protein also requires work energy but the amount is somewhat smaller than that for oil (46). Soyabeans and other legumes also acquire work energy for the symbiotic fixation of nitrogen (about 550 Kcal/lb).

Legumes fix nitrogem from the atmosphere by means of bacteria living in the nodules of its roots, thereby itself making larger growth. Some of the nitrogen so gathered is passed onto other non-legume plants associated with it, resulting in a larger growth of the non-legume and a higher protein content which increases its value as food (73, 94, 100). However, high nitrate concentration inhibited nodulation to a greater extent than higher ammonium concentrations although a small amount of combined nitrogen appeared to promote the process (80). Galal et al. (36) found that pod number and seed number per plant were about 30 to 50% more in solid soyabeans than in intercropped culture. He also noted that soyabean oil content was slightly affected but protein content increased in intercropped soyabean. Son et al. (86) found that plant height and protein content of soyabeans increased while branch number, number of pods per plant, grain yield, 100-seed weight and oil content decreased. Oil content of soyabeans was negatively correlated with protein content.

Shading accelerated the rate of loss of total nodule N_2-fixing activity since the energy for N_2-fixation is derived from photosynthesis which depends on light. Seed percent protein and oil content of the seed were virtually unaffected between 20 and 80% shade but at 93% shade, protein percent was the highest while oil was at its lowest percent (97). The effect of an inoculated companion legume on a non-legume may be similar to that obtainable by the application of nitrogenous manure to a non-legume in single culture (73). Maize associated with field beans gave increases of 12 to 14% dry matter and 59% crude protein over yields from monoculture maize (39). Kalaidzhieva (56) found the highest increases in crude protein yield from mixtures sown at 55,000 maize plus 350,000 soyabean plants per hectare without irrigation and from 60,000 maize plus 350,000 soyabean plants per hectare with irrigation compared with pure stands of maize.

Fred et al. (34), Lipman (65), Nicol (72) and Wilson (105) stated that the main justification for employing polyculture system with a legume and non-legume was to supply nitrogen to the latter and pointed out that an association of legumes and non-legumes can contain more N than either crop in pure stand even though crop yields need not be higher. In sorghum and soyabean mixtures, the roots of sorghum contained more N, and those of soyabeans less than when grown separately (22). Wahua et al. (96) found that protein yield of intercropped tall and semi-dwarf sorghum was reduced by 15 and 71%, respectively. With a dwarf cultivar, he found an increase of 15% seed protein and in all cases, sorghum grain oil was unaffected by intercropping. In contrast, he found lower soyabean oil content and unaffected soyabean percent seed protein when soyabean was associated with variable heights of sorghum. In his previous work on maize-soyabean association, he found 12% reduction in percent maize grain protein. Kaurov (58), Madhok (67) and Virtanen et al. (94) reported that when chick peas or peas were intercropped with oats, wheat and barley, the nitrogen content of small grains increased and that of peas decreased in comparison with sole crop. On a loamy soil near St. Augustine, Trinidad, Dalal (19) found that pigeon peas and maize planted in alternate rows produced more N than pure stands of maize or pigeon peas although the difference for pigeon peas was not significant.

MATERIALS AND METHODS

A short-season maize hybrid (*Zea mays* L., Michigan Hybrid 5802), a black bean (*Phaseolus vulgaris* L., variety San Fernando) and a maturity group II soyabean (*Glycine max*(L) Merill, cultivar Cole) were grown under intercropped culture and monoculture on the Michigan State University crop farm at East Lansing, Michigan during the 1978 season. The soil was classified as capac loam, 0-3% slopes (aeric ochraqualfs; fine loamy mixed, mesic).

Clover, which occupied the field during the preceding season was ploughed down on May 19, 1978 and disced three times before planting. A complete fertilizer 19-19-19 was broadcasted at a rate of 64 kg each of N-P_2O_5-K_2O per hectare on May 25, 1978 and worked into the soil in the last discing.

The component crops were hand planted on May 29, 30 and 31, 1978 for maize, beans and soyabean, respectively, in a 2x3x3 factorially arranged randomized complete block with four replications. Lasso herbicide (alachlor) was applied at a rate of 1.96 kg/ha a day after maize-soyabean combinations were planted. The eighteen treatments (maize-beans or maize-soyabean) which were planted in 3x4 meter plots consisted of two maize densities, three maize row widths, and three bean or soyabean configurations. Monoculture maize at both high and low densities and bean or soyabean at recommended rates (200,000 plants/ha for beans and 300,000 plants/ha for soyabeans) were included in each replication making a total of 21 treatments for each of the two intercropping experiments.

High seeding rates were used and plots were thinned three weeks after emergence to desired plant densities. The two maize densities, a low density of 22,500 plants/ha and a high density of 45,000 plants/ha were planted in the three row widths. In the first and second row widths, single maize rows were spaced 75 cm and 100 cm apart, respectively. In the third maize row width paired rows of maize were spaced 130 cm apart and the rows within pairs were separated by a width of 40 cm (see Figure 1). The legume species plant density remained constant throughout the experiment as the number of rows and their distances from maize rows were altered. The distance between maize and legume rows was 17, 25, and 37.5 cm in the 75 cm row width and 25, 38, and 50 cm in the 100 and 130 cm row widths (see Figure 1). In each row width, the shortest distance between maize and the legume species represented configuration level one, the next closest distance as level two and the distance farthest from maize rows as configuration level three.

Configuration levels one and two had two rows of legumes (beans or soyabeans) between the adjacent maize rows and their seeding rates were 7.5 and 10 (beans) and 11.25 and

15 (soyabeans) plants/meter of row in the 75 and 100 cm row width, respectively. In the third configuration level of the 75 and 100 cm row widths one row of legume was altered with one row of maize and their seeding rates were 15 and 20 (beans) and 22.5 and 30 (soyabeans) plants/meter of row, respectively. In the 130 cm maize row width, a constant double row of legumes with a constant seeding rate of 15 (beans) and 22.5 (soyabeans) plants/meter of row were planted in all three configuration levels. Soyabean spacing between adjacent legume rows at 75, 100 and 130 cm row widths for configuration levels one through three were 41x8, 25x8, 75x4, 50x6, 24x6, 100x3 and 80x4, 54x4 and 30x4 cm, respectively (see Figure 1 and Table 1 for dry bean row spacings).

Legume traits (plant height, nodes, branches, pods, racemes and dry matter weight) were determined at physiological maturity (when 90% of pods were yellow) by taking measurements on four random plants per plot.

The two experiments, that is, maize in association with dry beans and maize in association with soyabean, were kept weed free by hand during the growing season. All drv bean and a few soyabean plots were sprayed once with sevin (Carbaryl) to control Mexican bean beetle (Epilachna varivestis).

Rainfall during the course of the experiment was slightly less than average but was generally adequate and timely (Appendix A). Maize plants showed the rolled leaves

FIGURE 1. MAIZE AND DRY BEANS OR SOYABEANS ARRANGEMENTS IN EACH SPACING.

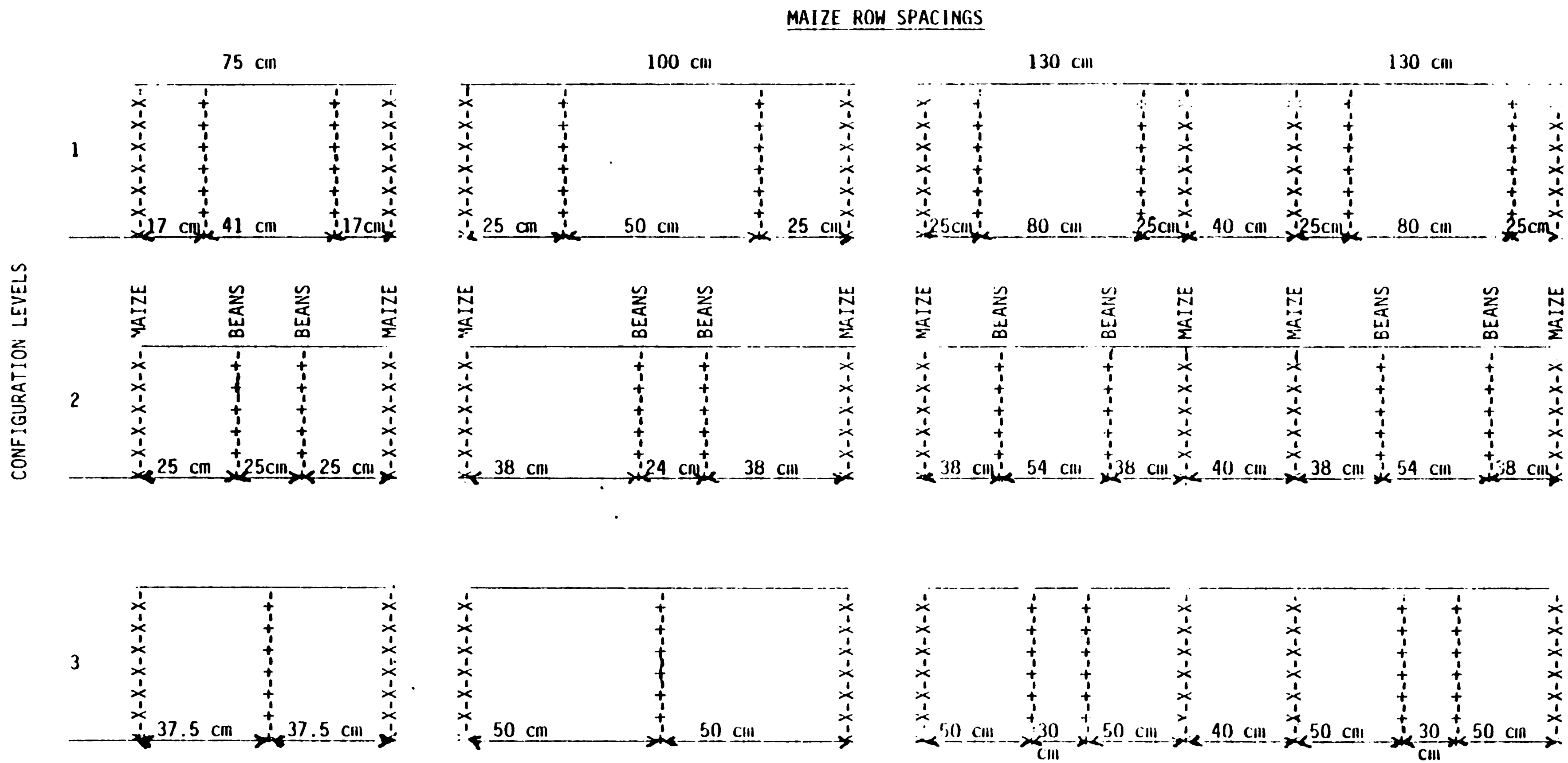

Table 1. Specifications in the Maize-Bean Association Experiment

Table 1. Specifications in the Maize-Bean Association Experiment

Treatment Combinations

		Maize				Beans			
No.	Distance of Bean Rows from Adjacent Maize Rows	Density (pl/ha)	Spacing (cm)	Plants/ Meter	Rows/ Plot	Density (pl/ha)	Spacing in Adjacent Rows (cm)	Plants/ Meter	Rows/ Plot
1	2 Bean Rows 17 cm away	45,000	75x29	3.4	5	200,000	41x13	7	8
2	2 Bean Rows 17 cm away	22,500	75x58	1.7	5	200,000	41x13	7	8
3	2 Bean Rows 25 cm away	45,000	75x29	3.4	5	200,000	25x13	7	8
4	2 Bean Rows 25 cm away	22,500	75x58	1.7	5	200,000	25x13	7	8
5	1 Bean Row 37.5 cm away	45,000	75x29	3.4	5	200,000	75x6	15	4
6	1 Bean Row 37.5 cm away	22,500	75x58	1.7	5	200,000	75x6	15	4
7	2 Bean Rows 25 cm away	45,000	100x22	4.5	4	200,000	50x10	10	6
8	2 Bean Rows 25 cm away	22,500	100x44	2.2	4	200,000	50x10	10	6
9	2 Bean Rows 38 cm away	45,000	100x22	4.5	4	200,000	24x10	10	6
10	2 Bean Rows 38 cm away	22,500	100x44	2.2	4	200,000	24x10	10	6
11	1 Bean Row 50 cm away	45,000	100x22	4.5	4	200,000	100x5	20	3
12	1 Bean Row 50 cm away	22,500	100x44	2.2	4	200,000	100x5	20	3
13	2 Bean Rows 25 cm away	45,000	130x22	4.5	4	200,000	80x6	15	4
14	2 Bean Rows 25 cm away	22,500	130x44	2.2	4	200,000	80x6	15	4
15	2 Bean Rows 38 cm away	45,000	130x22	4.5	4	200,000	54x6	15	4
16	2 Bean Rows 38 cm away	22,500	130x44	2.2	4	200,000	54x6	15	4
17	2 Bean Rows 50 cm away	45,000	130x22	4.5	4	200,000	30x6	15	4
18	2 Bean Rows 50 cm away	22,500	130x44	2.2	4	200,000	30x6	15	4
19	Monoculture Beans					200,000	50x10	10	7
20	Monoculture Maize	22,500	75x58	1.7	5				
21	Monoculture Maize	45,000	75x29	3.4	5				

Table 2. Specifications in the Maize-Soyabean Association Experiment

Treatment Combinations

No.	Distance of Soyabean Rows from Adjacent Maize Rows	Maize Density (pl/ha)	Maize Spacing (cm)	Maize Plants/ Meter	Maize Rows/ Plot	Soyabean Density (pl/ha)	Soyabean Spacing in Adjacent Rows (cm)	Soyabean Plants/ Meter	Soyabean Rows/ Plot
1	2 Rows 17 cm away	45,000	75x29	3.4	5	300,000	41x8	11	8
2	2 Rows 17 cm away	22,500	75x58	1.7	5	300,000	41x8	11	8
3	2 Rows 25 cm away	45,000	75x29	3.4	5	300,000	25x8	11	8
4	2 Rows 25 cm away	22,500	75x58	1.7	5	300,000	25x8	11	8
5	1 Row 37.5 cm away	45,000	75x29	3.4	5	300,000	75x4	22	4
6	1 Row 37.5 cm away	22,500	75x58	1.7	5	300,000	75x4	22	4
7	2 Rows 25 cm away	45,000	100x22	4.5	4	300,000	50x6	15	6
8	2 Rows 25 cm away	22,500	100x44	2.2	4	300,000	50x6	15	6
9	2 Rows 38 cm away	45,000	100x22	4.5	4	300,000	24x6	15	6
10	2 Rows 38 cm away	22,500	100x44	2.2	4	300,000	24x6	15	6
11	1 Row 50 cm away	45,000	100x22	4.5	4	300,000	100x3	30	3
12	1 Row 50 cm away	22,500	100x44	2.2	4	300,000	100x3	30	3
13	2 Rows 25 cm away	45,000	130x22	4.5	4	300,000	80x4	22	4
14	2 Rows 25 cm away	22,500	130x44	2.2	4	300,000	80x4	22	4
15	2 Rows 38 cm away	45,000	130x22	4.5	4	300,000	54x4	22	4
16	2 Rows 38 cm away	22,500	130x44	2.2	4	300,000	54x4	22	4
17	2 Rows 50 cm away	45,000	130x22	4.5	4	300,000	30x4	22	4
18	2 Rows 50 cm away	22,500	130x44	2.2	4	300,000	30x4	22	4
19	Pure Stand Soyabean					300,000	75x4	22	5
20	Monoculture Maize	22,500	75x58	1.7	5				
21	Monoculture Maize	45,000	75x29	3.4	5				

typical of water stress only once throughout the growing season.

Guard or border rows consisted of two lateral rows on each side and the first and last meter of each central row in configuration levels 1 and 2 at 75 and 100 cm row width, one lateral row in configuration level three of the same spacings and also in the three configuration levels in 130 cm row width. Only a single outside row of maize on each side of the plot, the first and last meter of each central row were considered as border rows. The harvest area was 4.5, 4.0, and 3.4 square meters for 75, 100 and 130 cm row widths, respectively. Dry bean and maize were hand harvested while soyabean was mechanically threshed in the field with a Hege small research plot combine. The seed samples were dried with forced air to constant moisture content, weighed and converted to kg/ha.

After each sample was weighed, maize, bean and soyabean samples were taken for percent protein and oil determination. Samples were ground by the use of 40 mesh UDY mill and percent protein and oil were determined in triplicate with the near infrared light reflectance grain analysis computer (48, 96).

The data were analyzed in accordance with a univariate analysis of variance. Since this method could not be used to compare each treatment with monoculture component crops, one-way analysis of variance was used to compare each character in a 2x3x3 arrangement with characters in pure culture.

RESULTS

1. Maize and Bean Association

Results of maize and beans planted simultaneously in associated culture indicated that density, spacing, configuration levels and interations of these factors did not significantly affect dry bean plant height and harvest index (Tables 3-5). The maize density effect upon beans was expressed in nodes per plant, branches per plant ($p < 0.05$), pods per plant, dry matter weight and racemes per plant ($p < 0.01$) (Table 3 and 4). Maize at 22,500 plants/ha significantly increased these characters of beans. One hundred seed weight, seed percent protein and yield of beans were significantly affected ($p < 0.01$, 0.05, 0.01, respectively) by maize density (Table 3 and 4). Bean yields and 100-seed weight were high at low density while percent protein in bean seed was high at 45,000 plants/ha. With the exception of 100-seed weight, these traits were not affected by spacing, configuration levels and their interactions. Spacing had effect on pods/plant ($p < 0.05$), 100-seed weight ($p < 0.01$) and dry matter weight ($p < 0.05$). Pods were significantly higher at 100 cm spacing at the low density than 75 and 100 cm at the high density. One hundred seed weight was significantly high at spacing three at the low density than spacing one at the

Table 3. Effect of Maize Density and Spacing on Bean Traits in Association with Maize

MEAN SQUARE

Source of Variation	Degrees of Freedom	Bean Height (cm)	Nodes/ Plant	Branches/ Plant	Pods/ Plant	Racemes/ Plant	Harvest Index (%)	100-Seed Weight (g)	Dry Matter Weight (g)	Percent Protein	Seed Yield (kg/ha)
Density	1	36.6939^{ns}	3.2089*	3.0835*	88.0022**	23.2335**	.0556^{ns}	3.6901**	3739.6835**	7.8738*	3164457.1022**
Spacing	2	109.8004^{ns}	1.6372^{ns}	.2118^{ns}	21.8637*	4.7735^{ns}	2.5251^{ns}	2.4462**	1582.3879*	.0475^{ns}	97563.0093^{ns}
Density X Spacing	2	24.0226^{ns}	.5972^{ns}	.1168^{ns}	.8068^{ns}	.1151^{ns}	2.4801^{ns}	.4001^{ns}	918.2435^{ns}	.1010^{ns}	16181.3301^{ns}
Error	66	39.6091	.5384	.4501	4.7238	1.8265	9.2122	.4586	420.8472	1.1849	59120.8186
	CV %:	12.38	6.17	38.56	19.00	18.69	4.74	3.71	23.57	4.14	15.21

*$P < 0.05$
**$P < 0.01$
ns Not Significant ($P > 0.05$)

Table 4. Effect of Maize Density and Bean Configuration on Bean Traits in Association with Maize

MEAN SQUARE

Source of Variation	Degrees of Freedom	Bean Height (cm)	Nodes/ Plant	Branches/ Plant	Pods/ Plant	Racemes/ Plant	Harvest Index (%)	100-Seed Weight(g)	Dry Matter Weight(g)	Percent Protein	Seed Yield (kg/ha)
Density	1	36.6939^{ns}	3.2088*	3.0835	88.0022**	23.2335**	.0556^{ns}	3.6901**	3739.6835**	7.8738**	3164457.1022**
Configuration	2	63.3579^{ns}	.1156^{ns}	.1002^{ns}	.4162^{ns}	1.0293^{ns}	4.3843^{ns}	.5487^{ns}	172.4262^{ns}	2.1551^{ns}	49936.2406^{ns}
Density X Configuration	2	51.3193^{ns}	.2905^{ns}	.1101^{ns}	5.6551^{ns}	.2318^{ns}	5.7518^{ns}	1.3993^{ns}	191.0935^{ns}	1.8332^{ns}	63471.5606^{ns}
Error	66	40.1893	.5938	.4537	5.2268	1.9365	9.0567	.4858	485.6081	1.0685	59131.0168
CV %:		12.48	6.48	38.71	19.98	19.25	4.70	3.81	25.32	3.93	15.21

*F < 0.05

**P < 0.01

ns Not Significant (P > 0.05)

Table 5. Effect of Spacing and Bean Configurations on Bean Traits in Association with Maize

MEAN SQUARE

Source of Variation	Degrees of Freedom	Bean Height (cm)	Nodes/ Plant	Branches/ Plant	Pods/ Plant	Racemes/ Plant	Harvest Index (%)	100-Seed Weight (g)	Dry Matter Weight (g)	Percent Protein	Seed Yield (kg/ha)
Spacing	2	109.8004	1.6372^{ns}	.2118^{ns}	21.8637*	4.7735^{ns}	2.5251	2.4462**	1582.3879*	.0475^{ns}	97563.0093^{ns}
Configur- ation	2	63.3579^{ns}	.1155^{ns}	.1001^{ns}	.4162^{ns}	1.0293^{ns}	4.3843^{ns}	.5487^{ns}	172.4262^{ns}	2.1551^{ns}	49936.2406^{ns}
Spacing X Configur- ation	4	19.5933^{ns}	.3782^{ns}	.2901^{ns}	9.8081^{ns}	2.2610^{ns}	2.7660^{ns}	.9244^{ns}	1083.6135^{ns}	.9552^{ns}	146275.3672
Error	63	39.5849	.6062	.5026	5.7353	2.1097	9.4157	.4756	455.1234	1.2404	101806.6642
CV %:		12.38	6.55	40.75	20.93	20.09	4.80	3.77	24.51	4.24	19.96

*P <0.50

**P <0.01

nsNot Significant (P>0.05)

high density. Dry matter weight was also significantly high at spacing three at the low density than spacing two at the high density.

Comparison of monoculture beans with associated culture showed that bean height (except treatment one which was significantly shorter), harvest index:

$$\frac{\text{Economic yield (seed)}}{\text{Total biological yield}} \times 100\%$$

and percent protein of bean seed were not significantly different from pure culture beans. However, pods per plant, racemes per plant, dry matter weight and yield of beans in association with maize were significantly lower ($p < 0.01$) than sole crop of beans. As shown in Tables 6.1 and 6.2, all intercropped treatments were significantly lower in 100-seed weight (except treatment 16), branches per plant (except treatments 10 and 14) and nodes per plant (except treatments 6, 8, 9, 12, 14, 15 and 16).

Maize in association with beans analysis indicated that maize 100-kernel weight, percent protein of maize, land equivalent ratio (LER) and yield were highly affected by maize density at the 1% probability level (Table 7 and 8). One hundred kernel weight and percent protein of maize were highest at low maize density while LER and yield were highest at 45,000 plants/ha. Percent oil of maize was not significantly different both within associated culture and when compared with monoculture maize at the high density, although maize at low density planted at the 75 cm row width with a

Table 6.1. Comparison of Bean Traits Associated with Maize to Monoculture Bean Traits

Table 6.1. Comparison of Bean Traits Associated with Maize to Monoculture Bean Traits

Treat-ment No.	Spacing (cm)	Distance of Bean Rows from Maize Rows	Maize Density (pl/ha)	Height (cm)	Nodes/ Plant	Branches/ Plant	Pods/ Plant	Racemes/ plant
1		2 Rows 17 cm away	45,000	46^{c*}	11.22^{de*}	1.12^{d*}	8.47^{g*}	5.80^{f*}
2		2 Rows 17 cm away	22,500	48^{bc}	11.85^{b-e}	1.67^{b-d}	11.30^{c-g}	7.10^{c-f}
3	75	2 Rows 25 cm away	45,000	46^{b}	11.30^{c-e}	1.85^{b-d}	9.35^{fg}	6.62^{c-f}
4		2 Rows 25 cm away	22,500	48^{bc}	11.85^{b-e}	1.60^{b-d}	10.72^{c-g}	7.10^{c-f}
5		1 Row 37.5 cm away	45,000	47^{bc}	11.10^{e}	1.47^{c-d}	9.85^{d-g}	6.35^{d-f}
6		1 Row 37.5 cm away	22,500	52^{a-c}	12.27^{a-d}	2.17^{bc}	12.47^{b-f}	7.92^{b-e}
7		2 Rows 25 cm away	45,000	46^{bc}	11.77^{b-e}	1.60^{b-d}	10.35^{c-g}	6.90^{c-f}
8		2 Rows 25 cm away	22,500	61^{a-c}	12.35^{a-c}	1.67^{b-d}	13.35^{bc}	7.67^{b-f}
9	100	2 Rows 38 cm away	45,000	53^{a-c}	12.10^{a-e}	1.35^{c-d}	9.67^{d-g}	6.10^{ef}
10		2 Rows 38 cm away	22,500	49^{a-c}	11.97^{b-e}	2.30^{a-c}	13.05^{bc}	8.40^{bc}
11		1 Row 50 cm away	45,000	52^{a-c}	12.02^{b-e}	1.75^{b-d}	11.52^{c-g}	6.62^{c-f}
12		1 Row 50 cm away	22,500	58^{a}	12.42^{ab}	1.72^{b-d}	12.77^{b-g}	7.40^{b-f}
13		2 Rows 25 cm away	45,000	51^{a-c}	11.57^{b-e}	1.50^{cd}	10.95^{c-g}	7.22^{b-f}
14		2 Rows 25 cm away	22,500	52^{a-c}	12.22^{a-d}	2.47^{ab}	14.17^{b}	9.17^{b}
15	130	2 Rows 38 cm away	45,000	53^{a-c}	11.22^{a-d}	1.55^{b-d}	13.25^{bc}	8.01^{b-e}
16		2 Rows 38 cm away	22,500	49^{a-c}	12.35^{a-c}	2.17^{bc}	12.67^{b-e}	8.10^{b-d}
17		2 Rows 50 cm away	45,000	52^{a-c}	11.77^{b-e}	1.60^{b-d}	9.60^{e-g}	6.35^{d-f}
18		2 Rows 50 cm away	22,500	52^{a-c}	11.60^{bc}	1.72^{b-d}	11.60^{c-g}	7.35^{b-f}
19	50	Monoculture	200,000	55^{ab}	13.17^{a}	3.15^{a}	21.65^{a}	12.12^{a}
		Grand Mean		51	11.96	1.81	11.98	7.49
		5% L.S.D.		9	1.08	.97	3.15	1.98
		CV %		12	6.4	37.7	18.6	18.7

*Means within a trait and followed by the same letter(s) are not significantly different at $P < 0.05$.

Table 6.2. Comparison of Bean Traits Associated with Maize to Monoculture Bean Traits

Table 6.2. Comparison of Bean Traits Associated with Maize to Monoculture Bean Traits

Treatment No.	Spacing (cm)	Distance of Bean Rows from Maize Rows	Maize Density (pl/ha)	Harvest Index (%)	100-Seed Weight (g)	Dry Matter Weight (g)	Percent Protein	Seed Yield (kg/ha)
1		2 Rows 17 cm away	45,000	63	17.72^{cd*}	71^{ef*}	26.93^{a*}	1304^{g-i*}
2		2 Rows 17 cm away	22,500	64	18.37^{c}	75^{d-f}	26.10^{a-c}	1785^{b-e}
3	75	2 Rows 25 cm away	45,000	63	16.87^{d}	72^{ef}	26.15^{a-c}	1190^{i}
4		2 Rows 25 cm away	22,500	63	18.17^{c}	65^{f}	25.03^{c}	1689^{b-f}
5		1 Row 37.5 cm away	45,000	64	18.32^{c}	90^{b-f}	26.67^{ab}	1529^{d-h}
6		1 Row 37.5 cm away	22,500	62	18.62^{bc}	95^{b-f}	26.55^{ab}	1893^{bc}
7		2 Rows 25 cm away	45,000	64	17.97^{c}	69^{ef}	27.01^{a}	1286^{hi}
8		2 Rows 25 cm away	22,500	62	18.02^{c}	97^{b-e}	25.77^{a-c}	1881^{bc}
9	100	2 Rows 38 cm away	45,000	63	17.92^{c}	73^{ef}	26.84^{a}	1415^{f-i}
10		2 Rows 38 cm away	22,500	64	18.30^{c}	97^{b-e}	25.34^{bc}	1848^{b-d}
11		1 Row 50 cm away	45,000	65	18.17^{c}	85^{c-f}	26.26^{a-c}	1637^{b-g}
12		1 Row 50 cm away	22,500	65	18.60^{bc}	103^{b-d}	26.68^{ab}	1961^{b}
13		2 Rows 25 cm away	45,000	63	18.62^{bc}	83^{c-f}	27.21^{a}	1328^{g-i}
14		2 Rows 25 cm away	22,500	64	18.57^{c}	115^{b}	26.14^{a-c}	1835^{b-e}
15	130	2 Rows 38 cm away	45,000	62	18.15^{c}	94^{b-f}	26.19^{a-c}	1505^{e-i}
16		2 Rows 38 cm away	22,500	64	19.50^{ab}	108^{bc}	26.08^{a-c}	1793^{b-e}
17		2 Rows 50 cm away	45,000	64	18.62^{bc}	76^{d-f}	26.11^{a-c}	1300^{g-i}
18		2 Rows 50 cm away	22,500	64	18.30^{c}	90^{b-f}	25.73^{a-c}	1583^{c-h}
19	50	Monoculture	200,000	64	19.65^{a}	156^{a}	25.82^{a-c}	3571^{a}
		Grand Mean		64	18.34	90	26.24	1702
		5% L.S.D.		NS	.90	29	1.50	337
		CV %		4.9	3.5	23	4.0	14

*Means within a trait and followed by the same letter(s) are not significantly different at $P < 0.05$.

single bean row, and maize at the same spacing but at high density with double bean rows planted 25 cm from maize rows gave an average of 4.14% and 4.13% oil, respectively, as compared to 3.98% oil in pure stand maize. Maize at the high density was taller than at the low density and was also affected by spacing while other maize traits were not significantly affected by spacing, configuration levels and factor interactions (Table 7, 8 and 9). Maize at spacing three at the high density was significantly taller than spacing one at the low density.

The comparison of maize yield in intercropping and monocropping systems indicated that maize yields at the low density and some combinations at the high density were significantly lower ($p < 0.05$) in general than maize in pure stand. Configurations one and two at 100 cm spacing, one and three at 130 cm spacing and configuration three at 75 cm spacing at the high maize density were not significantly different in grain yield from monoculture. Maize height and 100-kernel weight were either non-significant or significantly lower than the monoculture values. It was noted that at the high maize density, 100-seed weight and percent protein of maize obtained from configuration and spacing three were both significantly lower ($p < 0.05$) than pure stand maize (Table 10). In addition, percent protein of maize was lower than control at the 5% probability level at the configuration level two of the first row width. The LER comparison with monoculture maize was significantly high at the high maize

Table 7. Effect of Maize Density and Spacing on Maize Traits in Association with Beans

MEAN SQUARE

Source of Variation	Degrees of Freedom	Maize Height (cm)	100-Seed Weight (g)	Grain % Protein	Grain % Oil	Land Equivalent Ratios (LER)	Grain Yield (kg/ha)
Density	1	684.5000**	122.4612**	8.7014**	.0037^{ns}	.3828**	116304637.2000**
Spacing	2	243.2916*	9.0968^{ns}	.1698^{ns}	.0375^{ns}	.0251^{ns}	3161397.4938^{ns}
Density X Spacing	2	23.0416^{ns}	5.1129^{ns}	.0989^{ns}	.0022^{ns}	.0026^{ns}	1237208.0622^{ns}
Error	66	67.2853	4.8941	.2603	.0167	.0207	1227422.7310
	CV %:	4.40	5.90	5.71	3.22	12.40	15.89

*P < 0.05

**P < 0.01

^{ns} = Not significant (P > 0.05)

Table 8. Effect of Maize Density and Bean Configuration on Maize Traits in Association with Beans

MEAN SQUARE

Source of Variation	Degrees of Freedom	Maize Height (cm)	100-Seed Weight (g)	Grain % Protein	Grain % Oil	Land Equivalent Ratios (LER)	Grain Yield (kg/ha)
Density	1	684.50^{**}	122.4612^{**}	8.7014^{**}	$.0037^{ns}$	$.3828^{**}$	116304628.4000^{**}
Configuration	2	66.948^{ns}	3.3516^{ns}	$.7050^{ns}$	$.0097^{ns}$	$.0264^{ns}$	998968.2829^{ns}
Density X Configuration	2	12.7223^{ns}	11.7136^{ns}	$.3118^{ns}$	$.0269^{ns}$	$.0020^{ns}$	62777.8838^{ns}
Error	66	72.9417	4.8682	.2376	.0168	.0206	1328539.6821
	CV %:	4.58	5.88	5.46	3.23	12.40	16.53

$^{**}P < 0.01$

^{ns} = Not significant $(P > 0.05)$

Table 9. Effect of Maize Spacing and Bean Configuration on Maize Traits in Association with Beans

MEAN SQUARE

Source of Variation	Degree of Freedom	Maize Height (cm)	100-Seed Weight (g)	Grain % Protein	Grain % Oil	Land Equivalent Ratios (LER)	Grain Yield (kg/ha)
Spacing	2	243.2916^{*}	9.0968^{ns}	$.1698^{ns}$	$.0375^{ns}$	$.0251^{ns}$	3161397.4938^{ns}
Configur-ation	2	64.4715^{ns}	2.0173^{ns}	$.6912^{ns}$	$.0093^{ns}$	$.0235^{ns}$	628451.7985^{ns}
Spacing X Configura-tion	4	76.4244^{ns}	12.1598^{ns}	$.3859^{ns}$	$.0060^{ns}$	$.0195^{ns}$	3008723.1920^{ns}
Error	63	75.1869	6.3972	.3675	.0170	.0258	2960272.2326
	CV %:	4.65	6.74	6.79	3.24	13.86	24.67

$^{*}P < 0.05$

^{ns} = Not significant $(P > 0.05)$

Table 10. Comparison of Maize Traits in Association with Beans to Monoculture Maize Traits

Treat-ment No.	Spacing (cm)	Distance of Bean Rows from Maize Rows	Maize Density (pl/ha)	Height (cm)	100-Seed Weight (g)	Grain Percent Protein	Grain Percent Oil	LER*	Grain Yield (kg/ha)
1		2 Rows 17 cm away	45,000	185^{b-f**}	37.60^{a-d**}	9.11^{a-e**}	3.98^{a-e**}	1.06^{e-h**}	6780^{e-g**}
2		2 Rows 17 cm away	22,500	176^{f}	37.60^{a-d}	9.24^{a-e}	4.04^{a-e}	1.04^{f-h}	5299^{h}
3	75	2 Rows 25 cm away	45,000	185^{b-f}	35.20^{de}	8.12^{g}	4.13^{a}	1.18^{a-h}	8171^{b-e}
4		2 Rows 25 cm away	22,500	180^{d-f}	36.92^{b-d}	9.04^{a-e}	4.00^{a-e}	1.06^{e-h}	5676^{gh}
5		1 Row 37.5 cm away	45,000	190^{a-e}	36.10^{cd}	8.60^{d-f}	4.08^{a-c}	1.34^{a}	8812^{a-c}
6		1 Row 37.5 cm away	22,500	179^{ef}	39.32^{ab}	9.30^{a-c}	4.14^{a}	1.05^{f-h}	5074^{h}
7		2 Rows 25 cm away	45,000	184^{c-f}	35.77^{d}	8.58^{ef}	4.04^{a-e}	1.29^{ab}	9137^{ab}
8		2 Rows 25 cm away	22,500	180^{d-f}	39.22^{ab}	9.60^{a}	3.92^{c-e}	1.06^{d-h}	5206^{h}
9	100	2 Rows 38 cm away	45,000	192^{a-c}	37.40^{a-d}	8.72^{c-f}	4.06^{a-d}	1.26^{a-d}	8463^{a-d}
10		2 Rows 38 cm away	22,500	182^{c-f}	39.87^{a}	9.26^{a-d}	3.94^{b-e}	1.09^{c-h}	5460^{gh}
11		1 Row 50 cm away	45,000	192^{a-c}	37.47^{a-d}	8.78^{b-f}	3.89^{de}	1.24^{a-f}	7656^{c-e}
12		1 Row 50 cm away	22,500	191^{a-d}	39.60^{ab}	9.21^{a-e}	4.10^{ab}	1.13^{b-h}	5647^{gh}
13		2 Rows 25 cm away	45,000	191^{a-d}	35.95^{cd}	8.82^{b-e}	3.99^{a-e}	1.25^{a-e}	8606^{a-d}
14		2 Rows 25 cm away	22,500	190^{a-e}	39.05^{ab}	9.41^{ab}	3.99^{a-e}	1.12^{b-h}	6011^{f-h}
15	130	2 Rows 38 cm away	45,000	189^{b-f}	37.77^{a-d}	8.80^{b-f}	3.99^{a-e}	1.21^{a-g}	7738^{b-e}
16		2 Rows 38 cm away	22,500	185^{b-f}	39.07^{ab}	9.10^{a-e}	3.99^{a-e}	1.04^{gh}	5749^{f-h}
17		2 Rows 50 cm away	45,000	194^{a-c}	32.62^{e}	7.73^{g}	4.04^{a-e}	1.26^{a-c}	8838^{a-c}
18		2 Rows 50 cm away	22,500	183^{c-f}	38.70^{a-c}	9.34^{a-c}	3.94^{b-e}	1.18^{a-h}	7200^{d-f}
19	75	Maize	22,500	196^{ab}	39.55^{ab}	9.29^{a-c}	3.88^{e}	1.00^{h}	6775^{e-g}
20	75	Maize	45,000	201^{a}	37.87^{a-d}	9.24^{a-e}	3.98^{a-e}	1.00^{h}	9831^{a}
		Grand Mean		187	37.63	8.96	4.01	1.14	7106
		5% L.S.D.		11	2.90	.69	.18	.19	1474
		CV %		4	5.4	5.4	3.1	12.1	14

*Land Equivalent Ratio

**Means within a trait and followed by the same letter(s) are not significantly different at $P<0.05$.

density at configuration level three of the first row width and in all configuration levels of the second and third row spacings.

2. Maize and Soyabean Association

Results of maize and soyabeans planted simultaneously in associated culture are presented in Tables 11, 12 and 13. Maize density did not affect soyabean height to the first pod set, height to the tips and 100-seed weight. Soyabean nodes, branches, pods per plant, dry matter weight, oil and yield were significantly higher ($p < 0.01$) at 22,500 plants/ha than at 45,000 maize plants/ha, while soyabean protein was significantly high ($p < 0.01$) at the high maize density.

Maize spacing had no effect on soyabean height, nodes, branches, total pods per plant, 100-seed weight, dry matter weight, protein and soyabean oil percent (Table 11). Spacing had significant effect on soyabean number of pods on branches per plant and seed yield at the 5% probability level while configuration levels significantly affected ($p < 0.05$) percent protein in soyabean seed and 100-seed weight (Table 12). Density X configurations influenced soyabean yield at the 5% probability level (Table 12).

A oneway analysis of variance was conducted to compare each treatment in associated culture with pure culture soyabean (Table 14.1 and 14.2). It was found that height to first pod set was significantly higher in intercropped systems than in monoculture soyabean. However, yield, percent oil of soyabean seed, dry matter weight, nodes, branches and

Table 11. Effect of Maize Density and Spacing on Soyabean Traits in Association with Maize

MEAN SQUARE

Source of Variation	Degrees of Freedom	Height to 1st Pod Set (cm)	Height to Tip (cm)	Nodes/ Plant	Branches/ Plant	Pods on Branches/ Plant	Total Pods/ Plant	100-Seed Weight (g)	Dry Matter Weight (g)	Percent Protein	Percent Oil	Seed Yield (kg/ha)
Density	1	20.0556^{ns}	165.0139^{ns}	18.4022**	4.7022**	109.0272**	656.4272**	5.2272^{ns}	8032.7812**	9.7903**	1.5812**	2378126.0568**
Spacing	2	24.7287^{ns}	601.6179^{ns}	.9129^{ns}	1.6737^{ns}	42.1351*	106.7450^{ns}	6.2651^{ns}	641.0443^{ns}	.9388^{ns}	.0147^{ns}	214241.3804*
Density X Spacing	2	.6085^{ns}	25.4960^{ns}	.5260^{ns}	.0935^{ns}	6.6043^{ns}	8.1072^{ns}	.8435^{ns}	78.0954^{ns}	.9913^{ns}	.0855^{ns}	167678.1401^{ns}
Error	66	11.1908	207.0647	1.7715	.5824	13.1149	34.3210	2.3599	314.0246	1.3249	.1447	59461.6417
CV %:		18.15	12.72	8.50	-	-	26.91	7.30	23.72	3.05	2.05	22.52

*P< 0.05
**P<0.01
^{ns}Not Significant (P>0.05)

Table 12. Effect of Maize Density and Soyabean Configuration on Soyabean Traits in Association with Maize

MEAN SQUARE

Source of Variation	Degrees of Freedom	Height to 1st Pod Set (cm)	Height to Tip (cm)	Nodes/ Plant	Branches/ Plant	Pods on Branches/ Plant	Total Pods/ Plant	100-Seed Weight (g)	Dry Matter Weight (g)	Percent Protein	Percent Oil	Seed Yield (kg/ha)
Density	1	20.0556^{ns}	165.0139^{ns}	18.4022**	4.7022**	109.0272**	656.4272**	5.2272^{ns}	8032.7812**	9.7903**	1.5812**	2378126.0568**
Configur- ation	2	6.9112^{ns}	181.0067^{ns}	.1662^{ns}	.7887^{ns}	7.4022^{ns}	36.6817^{ns}	10.5010*	597.5710^{ns}	4.8466*	.1102^{ns}	120966.6067^{ns}
Density X Configur- ation	2	4.7551^{ns}	178.8772^{ns}	1.8485^{ns}	.2085^{ns}	12.6206^{ns}	69.0756^{ns}	1.1693^{ns}	410.1562^{ns}	1.7857^{ns}	.0742^{ns}	210899.8422*
Error	66	11.6050	215.1626	1.7541	.6057	13.9851	34.5966	2.2217	305.2796	1.1824	.1422	60978.4014
CV %:		18.48	12.97	8.46	-	-	27.02	7.08	23.39	2.88	2.03	22.81

$^{*}P<0.05$

$^{**}P<0.01$

^{ns}Not Significant ($P>0.05$)

Table 13. Effect of Maize Spacing and Soyabean Configuration on Soyabean Traits in Association with Maize

MEAN SQUARE

Source of Variation	Degrees of Freedom	Height to 1st Pod Set (cm)	Height to Tip (cm)	Nodes/ Plant	Branches/ Plant	Pods on Branches/ Plant	Total Pods/ Plant	100-Seed Weight(g)	Dry Matter Weight(g)	Percent Protein	Percent Oil	Seed Yield (kg/ha)
Spacing	2	24.7287^{ns}	601.6179^{ns}	.9129^{ns}	1.6737^{ns}	42.1351^{ns}	106.7450^{ns}	6.2651^{ns}	641.0443^{ns}	.9388^{ns}	.0148^{ns}	214241.3804^{ns}
Configuration	2	6.9112^{ns}	181.0067^{ns}	.1662^{ns}	.7887^{ns}	7.4022^{ns}	36.6817^{ns}	10.5010*	597.5710^{ns}	4.8466*	.1102^{ns}	120966.6067^{ns}
Spacing X Configuration	4	1.5950^{ns}	157.4533^{ns}	.8535^{ns}	.2794^{ns}	2.0376^{ns}	14.6492^{ns}	1.8708^{ns}	58.4381^{ns}	.8793^{ns}	.0423^{ns}	23392.6283^{ns}
Error	63	11.7406	204.6104	2.1052	.6450	15.3154	44.5376	2.1299	436.2810	1.3652	.1732	100038.8406
CV %:		18.59	12.65	9.27	-	-	30.65	6.94	27.96	3.10	2.24	29.21

*P <0.50
**P <0.01
ns Not Significant (P>0.05)

Table 14.1. Comparison of Soyabean Traits in Association with Maize to Soyabean Traits in Monoculture

Table 14.1. Comparison of Soyabean Traits in Association with Maize to Soyabean Traits in Monoculture

Treatment No.	Spacing (cm)	Distance of Soyabean Rows from Maize Rows	Maize Density (pl/ha)	Height to First Pod set (cm)	Height to Plant Tip (cm)	Nodes/ Plant	Branches/ Plant	Pods on Branches/ Plant	Total pods/ plant
1		2 Rows 17 cm away	45,000	19^{a*}	119^{ab*}	15^{b-e*}	$.50^{c-e*}$	1.55^{bc*}	16^{ef*}
2		2 Rows 17 cm away	22,500	19^{a}	120^{ab}	16^{b-e}	$.42^{c-e}$	2.35^{bc}	22^{b-f}
3	75	2 Rows 25 cm away	45,000	19^{a}	116^{ab}	14^{b-e}	$.05^{e}$	$.25^{c}$	14^{f}
4		2 Rows 25 cm away	22,500	17^{a}	118^{ab}	16^{b-e}	$.67^{b-e}$	1.47^{bc}	20^{c-f}
5		1 Row 37.5 cm away	45,000	20^{a}	115^{ab}	14^{de}	$.47^{c-e}$	1.22^{bc}	18^{df}
6		1 Row 37.5 cm away	22,500	19^{a}	123^{a}	16^{b-d}	1.15^{b-e}	3.67^{bc}	27^{b-d}
7		2 Rows 25 cm away	45,000	18^{a}	101^{b}	14^{c-e}	$.17^{de}$	$.55^{c}$	16^{ef}
8		2 Rows 25 cm away	22,500	19^{a}	112^{ab}	16^{b-d}	1.30^{bc}	5.05^{bc}	24^{b-e}
9	100	2 Rows 38 cm away	45,000	17^{a}	112^{ab}	15^{b-e}	$.92^{b-e}$	2.85^{bc}	21^{c-f}
10		2 Rows 38 cm away	22,500	18^{a}	103^{ab}	15^{b-e}	1.02^{b-e}	3.55^{bc}	21^{c-f}
11		1 Row 50 cm away	45,000	20^{a}	115^{ab}	14^{b-e}	$.50^{c-e}$	2.37^{bc}	18^{d-f}
12		1 Row 50 cm away	22,500	17^{a}	111^{ab}	15^{b-e}	1.22^{b-d}	4.12^{bc}	24^{b-e}
13		2 Rows 25 cm away	45,000	18^{a}	107^{ab}	14^{e}	$.42^{c-e}$	1.22^{bc}	18^{d-f}
14		2 Rows 25 cm away	22,500	17^{a}	122^{a}	16^{b}	1.02^{b-e}	7.22^{b}	30^{b}
15	130	2 Rows 38 cm away	45,000	17^{a}	103^{ab}	15^{b-e}	1.05^{b-e}	3.27^{bc}	22^{b-f}
16		2 Rows 38 cm away	22,500	16^{a}	101^{b}	15^{b-e}	1.25^{b-d}	4.05^{bc}	23^{b-f}
17		2 Rows 50 cm away	45,000	17^{a}	112^{ab}	16^{b-e}	1.02^{b-e}	3.35^{bc}	21^{b-f}
18		2 Rows 50 cm away	22,500	16^{a}	112^{ab}	16^{bc}	1.65^{b}	7.30^{b}	27^{bc}
19	75	Monoculture	300,000	11^{b}	104^{ab}	18^{a}	4.22^{a}	26.85^{a}	57^{a}
		Grand Mean		18	112	15	1.00	4.33	23
		5% L.S.D.		4	20	1	1.11	6.07	9
		CV %		19	12	8			27

*Means within a trait and followed by the same letter(s) are not significantly different at $P < 0.05$

Table 14.2. Comparison of Soyabean Traits in Association with Maize to Soyabean traits in Monoculture

Table 14.2. Comparison of Soyabean Traits in Association with Maize to Soyabean traits in Monoculture

Treat-ment No.	Spacing (cm)	Distance of Soyabean Rows from Maize Rows	Maize Density (pl/ha)	100-Seed Weight (g)	Dry Matter Weight (g)	Seed Percent Protein	Seed Percent Oil	Seed Yield (kg/ha)
1		2 Rows 17 cm away	45,000	20.42^{b-d*}	60^{fg*}	38.31^{ab*}	18.63^{bc*}	920^{f-h*}
2		2 Rows 17 cm away	22,500	21.67^{a-c}	78^{b-g}	37.93^{a-c}	18.66^{bc}	1564^{b}
3	75	2 Rows 25 cm away	45,000	20.52^{b-d}	54^{g}	38.24^{ab}	18.37^{bc}	909^{f-h}
4		2 Rows 25 cm away	22,500	21.62^{a-c}	74^{b-g}	38.16^{ab}	18.58^{bc}	1291^{b-e}
5		1 Row 37.5 cm away	45,000	21.82^{a-c}	62^{e-g}	37.49^{a-e}	18.58^{bc}	813^{h}
6		1 Row 37.5 cm away	22,500	22.30^{ab}	94^{bc}	36.41^{c-e}	18.86^{b}	1447^{b-d}
7		2 Rows 25 cm away	45,000	19.15^{d}	56^{fg}	38.24^{ab}	18.47^{bc}	852^{gh}
8		2 Rows 25 cm away	22,500	20.40^{b-d}	82^{b-f}	37.78^{a-d}	18.79^{b}	1533^{bc}
9	100	2 Rows 38 cm away	45,000	20.82^{a-d}	70^{c-e}	37.53^{a-e}	18.49^{bc}	1115^{d-h}
10		2 Rows 38 cm away	22,500	19.85^{cd}	71^{c-g}	37.82^{a-c}	18.59^{bc}	1187^{c-g}
11		1 Row 50 cm away	45,000	21.10^{a-d}	66^{d-g}	37.55^{a-e}	18.34^{bc}	1016^{e-h}
12		1 Row 50 cm away	22,500	21.42^{a-c}	89^{b-e}	36.24^{de}	18.83^{b}	977^{e-h}
13		2 Rows 25 cm away	45,000	21.42^{a-c}	62^{fg}	38.78^{a}	18.15^{c}	847^{gh}
14		2 Rows 25 cm away	22,500	21.65^{a-c}	101^{b}	37.23^{a-e}	18.85^{b}	1258^{b-f}
15	130	2 Rows 38 cm away	45,000	20.22^{b-d}	68^{c-g}	38.29^{ab}	18.44^{bc}	799^{h}
16		2 Rows 38 cm away	22,500	20.25^{b-d}	83^{b-f}	37.58^{a-e}	18.64^{bc}	1042^{e-h}
17		2 Rows 50 cm away	45,000	21.47^{a-g}	75^{b-g}	38.49^{ab}	18.48^{bc}	834^{gh}
18		2 Rows 50 cm away	22,500	22.65^{a}	93^{b-d}	37.13^{b-e}	18.82^{b}	1077^{e-h}
19	75	Monoculture	300,000	21.22^{a-d}	169^{a}	36.19^{e}	19.53^{a}	2535^{a}
		Grand Mean		21.05	79	37.65	18.64	1159
		5% L.S.D.		2.09	27	1.57	.56	362
		CV %		7.0	23	2.9	2.1	22

*Means within a trait and followed by the same letter(s) are not significantly different at $P < 0.05$

pods per plant were significantly lower in associated culture than in monoculture soyabean. Plant height to the tip and 100-seed weight were not signficantly different from the sole crop soyabeans. Furthermore, it was noted that some intercropped treatments had significantly higher seed percent protein than the control (Table 14.2).

Unlike soyabean, maize yield in association with soyabean was significantly higher ($p < 0.01$) at 45,000 plants/ha than at a density of 22,500 plants/ha. Similarly, maize height was affected by maize density being significantly high ($p < 0.05$) at 45,000 plants/ha. Percent protein of maize and 100-kernel weight were generally high at the 1% probability level at the low maize density (Table 15 and 16). It was observed that the same combinations with high 100-kernel weight were also high in percent protein of maize (Table 18). LER and percent oil of maize were not affected by maize density.

Spacing and density X spacing had no significant effect on height, oil percent, LER and yield but row width and density X spacing significantly affected ($p < 0.05$) 100-kernel weight and grain percent protein. Spacing three at the low maize density was significantly high in 100-kernel weight than spacing one and three at the high maize density. Percent protein of maize was significantly lower in spacings one and three at the high maize density than in spacing three at the low maize density.

Soyabean configurations significantly affected maize

Table 15. Effect of Maize Density and Spacing on Maize Traits in Association with Soyabeans

MEAN SQUARE

Source of Variation	Degrees of Freedom	Maize Height (cm)	100-Seed Weight (g)	Grain % Protein	Grain % Oil	Land Equivalent Ratios (LER)	Grain Yield (kg/ha)
Density	1	420.50^{*}	343.6568^{**}	4.4501^{**}	$.0026^{ns}$	$.0029^{ns}$	37124764.7334^{**}
Spacing	2	18.50^{ns}	48.0629^{*}	$.4533^{*}$	$.0204^{ns}$	$.0072^{ns}$	667445.9959^{ns}
Density X Spacing	2	82.6666^{ns}	71.4176^{**}	$.9453^{**}$	$.0071^{ns}$	$.0065^{ns}$	1066827.6801^{ns}
Error	66	77.4949	13.1389	.1287	.0109	.0374	1730986.1026
	CV %:	4.72	10.14	4.01	2.60	18.98	21.53

$^{*}P \leqslant 0.05$

$^{**}P < 0.01$

^{ns} = Not significant $(P > 0.05)$

Table 16. Effect of Maize Density and Soyabean Configuration on Maize Traits in Association with Soyabeans

MEAN SQUARE

Source of Variation	Degrees of Freedom	Maize Height (cm)	100-Seed Weight (g)	Grain % Protein	Grain % Oil	Land Equivalent Ratios (LER)	Grain Yield (kg/ha)
Density	1	420.50^{*}	343.6568^{**}	4.4501^{**}	$.0026^{ns}$	$.0029^{ns}$	37124764.7339^{**}
Configuration	2	292.7916^{*}	116.7904^{**}	$.8197^{**}$	$.0122^{ns}$	$.0701^{ns}$	10718586.0134^{**}
Density X Configuration	2	2.0416^{ns}	$.8993^{ns}$	$.1045^{ns}$	$.0846^{**}$	$.0544^{ns}$	410939.4318^{ns}
Error	66	71.62662	13.1932	.1431	.0088	.0341	1446281.5035
	CV %:	4.54	10.16	4.22	2.33	18.11	19.68

$^{*}P < 0.05$

$^{**}P < 0.01$

^{ns}Not Significant ($P > 0.05$)

Table 17. Effect of Maize Spacing and Soyabean Configuration on Maize traits in Association with Soyabean

MEAN SQUARE

Source of Variation	Degree of Freedom	Maize Height (cm)	100-Seed Weight (g)	Grain % Protein	Grain % Oil	Land Equivalent Ratios (LER)	Grain Yield (kg/ha)
Spacing	2	18.50^{ns}	48.0629^{*}	$.4533^{ns}$	$.0204^{ns}$	$.0072^{ns}$	667445.99^{ns}
Configur-ation	2	292.7916^{*}	116.7904^{**}	$.8197^{**}$	$.0122^{ns}$	$.0701^{ns}$	10718586.01^{**}
Spacing X Configur-ation	4	95.2291^{ns}	49.3358^{*}	$.7457^{**}$	$.0227^{ns}$	$.0269^{ns}$	1556566.6986^{ns}
Error	63	75.1428	14.6466	.1621	.0099	.0355	1997461.3340
	CV %:	4.65	10.71	4.49	2.47	18.49	23.13

$^{*}P < 0.05$

$^{**}P < 0.01$

^{ns}Not significant (P >0.05)

Table 18. Comparison of Maize Traits Associated with Soyabean to Monoculture Maize Traits

Treat-ment No.	Spacing (cm)	Distance of Soyabean Rows from Maize rows	Maize Density (pl/ha)	Height (cm)	100-Seed Weight (cm)	Grain Percent Protein	Grain Percent Oil	LER*	Grain Yield (kg/ha)
1		2 Rows 17 cm away	45,000	191 [a-d]**	36.07 [d-f]**	8.93 [d-h]**	4.07 [a-d]**	.98 [ab]**	6339 [c-f]**
2		2 Rows 17 cm away	22,500	181 [cd]	35.57 [ef]	8.85 [fi]	4.18 [a]	1.08 [ab]	4984 [e-h]
3	75	2 Rows 25 cm away	45,000	186 [b-d]	30.35 [h]	8.25 [j]	4.01 [b-f]	.95 [ab]	6100 [c-g]
4		2 Rows 25 cm away	22,500	181 [cd]	35.67 [d-f]	9.13 [c-g]	4.01 [b-f]	.92 [ab]	4272 [h]
5		1 Row 37.5 cm away	45,000	196 [ab]	33.27 [fg]	8.81 [g-i]	4.13 [ab]	1.14 [a]	8338 [ab]
6		1 Row 37.5 cm away	22,500	196 [ab]	40.72 [ab]	9.59 [ab]	3.93 [ef]	1.13 [ab]	5787 [c-h]
7		2 Rows 25 cm away	45,000	181 [cd]	30.75 [gh]	8.47 [ij]	3.95 [d-f]	.94 [ab]	6156 [c-g]
8		2 Rows 25 cm away	22,500	179 [d]	37.32 [c-e]	8.82 [g-i]	4.09 [a-c]	1.02 [ab]	4574 [h]
9	100	2 Rows 38 cm away	45,000	190 [a-d]	41.17 [ab]	9.79 [a]	3.91 [f]	1.10 [ab]	6733 [b-d]
10		2 Rows 38 cm away	22,500	179 [d]	36.82 [c-e]	9.30 [b-e]	3.99 [c-f]	.98 [ab]	5381 [d-h]
11		1 Row 50 cm away	45,000	193 [a-c]	38.45 [bc]	8.91 [e-h]	4.09 [a-c]	1.10 [ab]	7249 [bc]
12		1 Row 50 cm away	22,500	189 [b-d]	39.42 [a-c]	9.32 [b-d]	3.95 [d-f]	.99 [ab]	6310 [c-f]
13		2 Rows 25 cm away	45,000	191 [a-d]	29.52 [h]	8.29 [j]	3.99 [c-f]	.98 [ab]	6644 [b-e]
14		2 Rows 25 cm away	22,500	187 [b-d]	37.10 [c-e]	9.18 [c-g]	3.97 [c-f]	1.08 [ab]	6045 [c-g]
15	130	2 Rows 38 cm away	45,000	181 [cd]	26.20 [i]	8.38 [j]	4.03 [b-f]	.98 [ab]	6708 [b-d]
16		2 Rows 38 cm away	22,500	182 [cd]	37.60 [c-e]	9.29 [b-e]	4.06 [a-d]	.87 [b]	4783 [f-h]
17		2 Rows 50 cm away	45,000	188 [b-d]	36.17 [de]	8.58 [h-j]	4.12 [ab]	1.06 [ab]	7991 [bc]
18		2 Rows 50 cm away	22,500	189 [a-d]	41.65 [a]	9.34 [bc]	4.01 [b-f]	1.04 [ab]	6398 [c-f]
19	75	Monomaize	22,500	196 [ab]	39.55 [a-c]	9.30 [b-e]	3.93 [f]	1.00 [ab]	6776 [b-d]
20	75	Monomaize	45,000	201 [a]	37.87 [cd]	9.24 [b-f]	4.02 [b-f]	1.00 [ab]	9831 [a]
		Grand Mean		187	36.03	8.99	4.02	1.02	6330
		5% L.S.D.		12	2.81	.40	.13	.26	1717
		CV %		4	5.5	3.2	2.2	18.4	19

*Land Equivalent Ratio

**Means within a trait and followed by the same letter(s) are not significantly different at $P < 0.05$.

height, 100-kernel weight, grain percent protein and yield (Table 16). In the third soyabean arrangement, maize at the high density was significantly taller ($p < 0.05$) than in the second soyabean configuration at the low maize densitv while, at the low maize density, third sovabean configuration gave a significantly higher ($p < 0.01$) 100-kernel weight than the rest of the soyabean row arrangements in all row widths and densities. Similarly, the third sovabean arrangement at the low maize density was significantly higher ($p < 0.01$) in protein content than the other arrangements except in the second soyabean configuration at the low maize density. Maize yield at the third soyabean row arrangement at the high maize density was significantly higher ($p < 0.01$) than in the first and second soyabean row arrangements at the low maize density.

Densitv X configurations was only observed in grain percent oil in which the third soyabean configuration at the high density was significantly higher than the second configuration at the same densitv and at the same configuration at the low maize density. Similarly, spacing X soyabean configurations was highly significant in 100-kernel weight and grain percent protein (Table 17). The second configuration of the second spacing was significantly higher ($p < 0.01$) than all spatial arrangements in the third spacing, first configuration of the same spacing and configurations one and two of first spacing while 100-kernel weight in the third soyabean arrangement at the second row width was significantly higher than in configurations two, one, and one and nutrients during maize grain filling stage and therefore photosynthate storage in sinks (seeds) was much higher at the low density than at the high maize density in which intra-specific competition for these resources was still a major factor and therefore there was a reduced carbohydrate for grain filling. It appeared that 100-kernel weight also depended on number of kernels per unit area or per cob since treatments with the highest yield had the highest kernels per hectare too, but were the lowest in 100-kernel weight.

Similarly, percent protein of maize was significantly higher at the low maize density than at the high density probably due to less competition for soil nitrogen. In addition, available light and nitrate might have enhanced enzyme nitrate reductase activity in nitrogen assimilation at the low maize density than at the high density. The increase may also be attributed to the fact that beans in low maize density were exposed to less inter-crop competition and shading and therefore were probably able to form active nodules which in turn fixed atmospheric nitrogen for their use and surplus nitrogen were probably transferred to maize possibly through bean leaf leachate (during heavy rainfall), stem and root excretion, nodule exudation or through bean leaf and nodule decomposition. Such additional supply of nitrogen might have contributed to the high grain percent protein at the low density than at the high maize density. Other authors (2, 73, 94, 100) indicated that some of the fixed nitrogen was passed onto other non-legume two in spacings one, two and three, respectively, at the 5% probability level.

Comparison between monocropping and associated culture indicated that monoculture maize yielded significantly higher than intercropped maize except when maize was spaced at 75 cm and interplanted with a single row of soyabeans at the high density. Likewise, percent protein of maize in some treatments was significantly lower than control and others were not significantly different from pure culture maize. Only treatment 9 was significantly higher in grain percent protein at the high maize density in the second configuration and row width as compared with monoculture maize. Furthermore, maize at the low density with rows spaced 75 cm apart and interplanted with double soyabean rows 17 cm from maize rows gave significantly higher ($p < 0.05$) percent oil of maize than monoculture maize. Other treatment combinations were not significantly different from monoculture maize oil. Comparison of 100-kernel weight in associated culture with monoculture maize indicated a non-significant effect, some intercropped treatments were significantly lower in 100-kernel weight than pure stand maize. Treatments 6, 9 and 18 gave significantly higher 100-kernel weight than monoculture maize as shown in Table 18. Similarly, maize height was either non-significant or significantly shorter than maize in monocropping systems. Land equivalent ratio (LER) was not significantly different from pure culture.

DISCUSSION

1. Maize and Bean Association

Results of maize in association with beans indicated that maize at the high density was taller than that of the low densitv. High maize density with rows spaced 130 cm apart (with paired maize rows 40 cm apart) were significantly taller than any other treatments possibly due to reduced light intensitv which might have stimulated IAA activity in promoting internode extension through the alteration of IAA oxidase inhibitor, leading to increased maize height since these paired rows were only 40 cm apart. Maize plants at the low density experienced somewhat strong light intensity which suppressed IAA activity upon internode extension, resulting in shorter though generally sturdier plants than at the high density.

Weight of 100-kernels of maize in association with beans was significantly higher at the low maize density than at the high density presumably because at the lower populational levels, each plant simply has had greater opportunity to photosynthesize and to store temporarily carbohydrates and nitrogen assimilates for use later in seed filling. Furthermore, beans matured after two and a half months thus eliminating inter-crop competition for moisture and associated with it, resulting in a large growth of the non-legume and a high protein content which increased its value as food. However, Wilson (105) pointed out that the direct transfer of nitrogen between the legume and non-legume appeared to be relatively unimportant for high protein content of the non-legume.

Monoculture maize at the high density had a mean percent protein of maize of 9.24 and the low density monoculture maize percent protein was 9.29. It was concluded that soil nitrogen availability in both monoculture treatments was used to increase kernels/cob rather than percent protein, otherwise, one would expect to obtain higher percent protein in the low density than in the high density monoculture maize. Since the highest percent protein of maize obtained from intercropped low density maize (though not significantly different from monoculture) was 9.60, the difference in percent protein could not be due to less intra and interspecific competition for nutrients only but also due to nitrogen supply from beans which were presumably transferred to maize when kernels/cob were already initiated. Nevertheless, it appeared that both fixed and residual nitrogen might significantly contribute more to succeeding non-legume crop than the associated one. Gorlitz (39) found a significant increase in grain percent protein in maize field bean mixtures.

Percent oil of maize was not significantly different in maize-bean association. Comparison between intercropped percent oil of maize with pure culture maize did not show any difference, indicating that neither interspecific nor intraspecific competition for environmental factors affected percent oil. Wahua (96) found no effect on sorghum percent oil of grain when sorghum was intercropped with soyabeans. Grain yield and land equivalent ratios (LER) of maize in association with beans (treatments 5, 7, 9, 13, 17 for the former and 5, 7, 9, 11, 13, 15, 17, for the latter) were significantly high at the high maize density.

The use of optimum plant density resulted in more efficient exploitation of the soil resources and light. Yield was significantly high when maize rows were spaced 100 and 130 cm apart with double bean rows and 75 cm apart with a single bean row. Since yield from these combinations did not significantly differ from monoculture maize, it indicated that San Fernando in appropriate arrangement did not suppress maize yield and thus any bean yield harvested from these combinations was an advantage for the subsistence farmers in total grain yield (maize plus beans) for food and net income. Combined yield (maize plus beans) was 10423 kg/ha and 9880 kg/ha at bean configurations one and two, respectively, at 100 cm row width; 9935 and 10138 kg/ha in bean arrangements one and three, respectively, at 130 cm maize row spacing and 10341 kg/ha at configuration three of 75 cm row width. At the current prices of 51 and 8 ¢/kg black beans and maize, respectively, the yield above c

s

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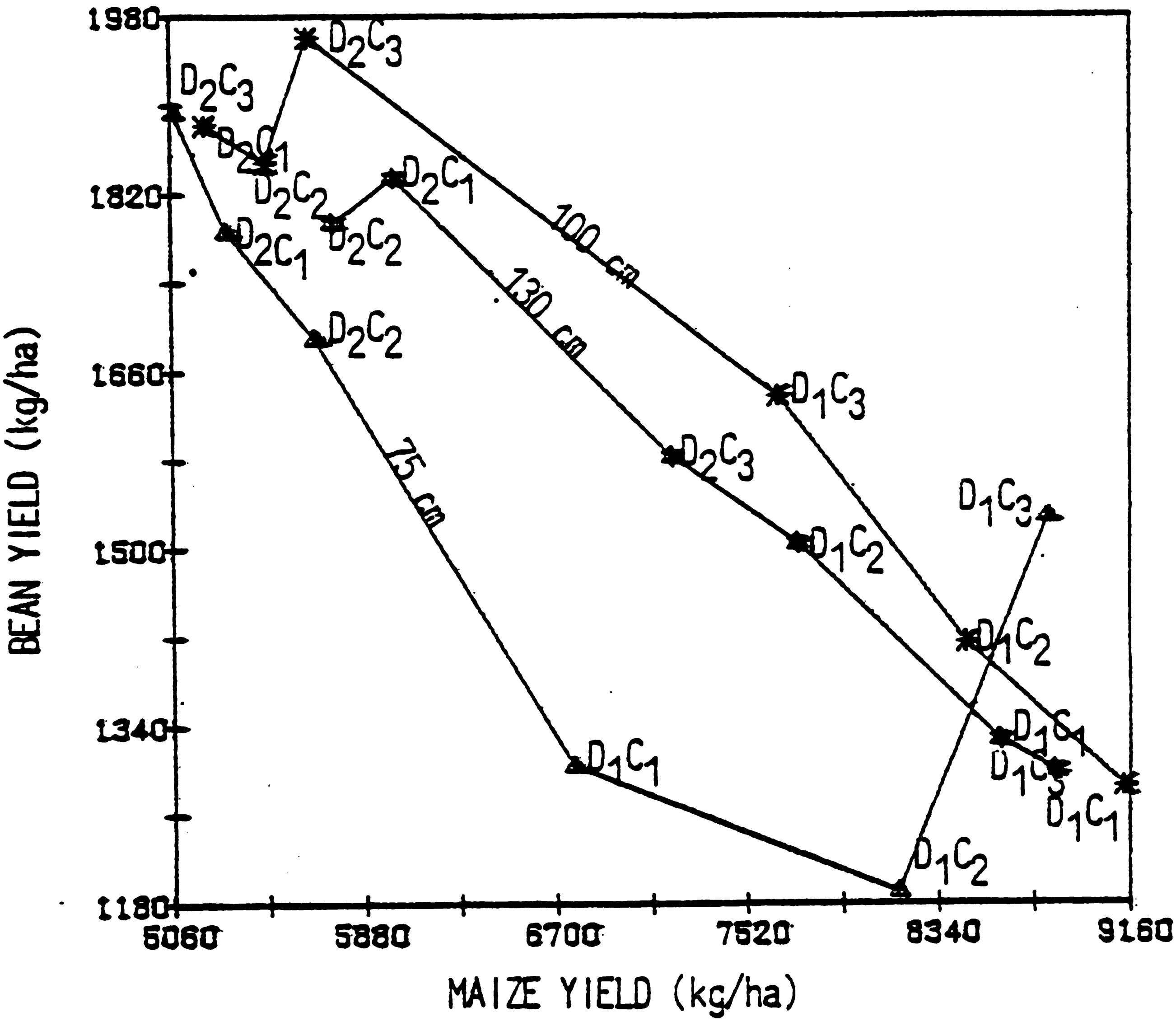
a

l

represented an economic return of $1386, 1399; 1365, 1370 and $1484, respectively. Maize yield in monoculture was 9831 kg/ha and 3571 kg/ha for beans, representing a cash return of $786 and $1821, respectively. It was therefore obvious that in this case the farmer lost money by engaging himself in intercropping instead of growing monoculture beans.

Francis et al. (31) found that at yield levels above 3,000 kg/ha, beans in monoculture gave higher economic returns than an associated culture. In places where land is limited, planting a single row of beans between maize rows spaced 75 cm apart would provide the best intercrop combination in terms of combined yield, protein and cash return. (Figure 2 and Table 19). This combination would provide the farmer with 90%, 43% and 80% of pure culture maize and bean yield and of pure stand bean economic return/ha, respectively. CIAT (14) reported a 20-30% and 51% yield reduction of maize and beans, respectively. Treatments 5, 7, 9, 13 and 17 provided better utilization of available resources such as labour, land and environmental factors as compared to monoculture. Osiru et al. (75) concluded that yield advantages of the mixtures of dwarf sorghum and beans were due to different rooting patterns which provided a more efficient utilization of the soil resources. However, Willey (101) suggested that the yield advantage might be due more to the efficient utilization of light by the combination of a tall maize with a short bean.

Figure 2. Effect of maize density, spacing and bean configuration on maize and bean yields.



D_1 = Maize density (45,000 plants/ha)

D_2 = Maize density (22,500 plants/ha)

C_1 - C_3 = Configuration levels.

Note: D_1C_3 of 75 cm row spacing provided the best combination for land use efficiency, combined yield and economic returns.

It should be noted that intercropping maize with beans may affect the yield (quantity) of one or both component crops but not the protein and oil (quality) content. Maize has a low percent protein and oil and therefore a small amount of stored energy is used to synthesize these components. Consequently, the effect of reduced energy supply in associated culture did not significantly alter the contents of protein and oil as compared with the monoculture maize components.

Because bean yields were low in the high maize density due to severe competition for available moisture, light and nutrients, LER reached only as high as 1.34. It was concluded that efficient use of natural resources increased with the addition of beans in associated culture. Francis (29) reported an LER greater than unity and as high as 1.88 for maize in association with beans. Yields of both component crops were reduced but their total yield per unit area was higher than their pure stand yields. LER values of 1.21 to 1.34 obtained from this experiment were highly significant indicating that up to 1.34 hectares of pure stand crops would be required to produce the same yield of one hectare of associated culture.

Bean height in associated culture was not significantly affected as compared with monoculture (except one treatment which was significantly shorter) indicating that probably bean plants completed their vegetative cycle before maize was vigorous enough to affect this character. Partial shading at that time was not severe enough to significantly promote bean height by internode extension. Nodes of bean plant were high in low maize density due probably to adequate availability of nutrients, moisture, space and solar energy for branch development. Furthermore, the growth habits of the two species differred in time so that beans had their peak demands of resources before maize. In addition, more carbohydrates were presumably produced in lower leaves, which were possibly transported to roots and nodules for N-fixation. Consequently, optimum plant growth was greatly promoted as a result of fixed nitrogen. Number of branches per plant in associated culture was reduced from 31% to 64% when compared with their pure stands. The reduction was more outstanding in the high density with rows spaced 75 cm apart with two bean rows planted 17 cm away from maize rows. Indeed, both intra and inter-crop competition for moisture, nutrient and available light were the major factors which contributed to low branch set per plant since these rows were crowded together. Comparison of associated culture nodes per plant and bean height with monoculture beans showed that some treatments had less nodes per plant than the control while their plant heights were not significantly different, supporting the commonly accepted concept that height was not only a function of nodes per plant but also a function of inter-node length.

Interspecific and intraspecific competition for environmental factors adversely affected the number of bean pods and number of racemes per plant as compared with pure stand beans. These traits were associated with vigorous vegetative growth of maize which imposed both a shading effect and severe interspecific competition for natural resources. Reduced uptake of resources might have lowered the rate of photosynthesis which resulted in reduced amount of carbohydrates for the formation and development of pods and racemes. Comparison between pure culture and intercropped beans indicated that racemes and pods were reduced from 24 to 51% and 30 to 60%, respectively. Bean 100-seed weight was also reduced in associated culture from 5 to 14% compared with pure culture. Beans in association appeared to have responded to competition for light and moisture through the reduction of number of branches and pods per plant and dry matter weight.

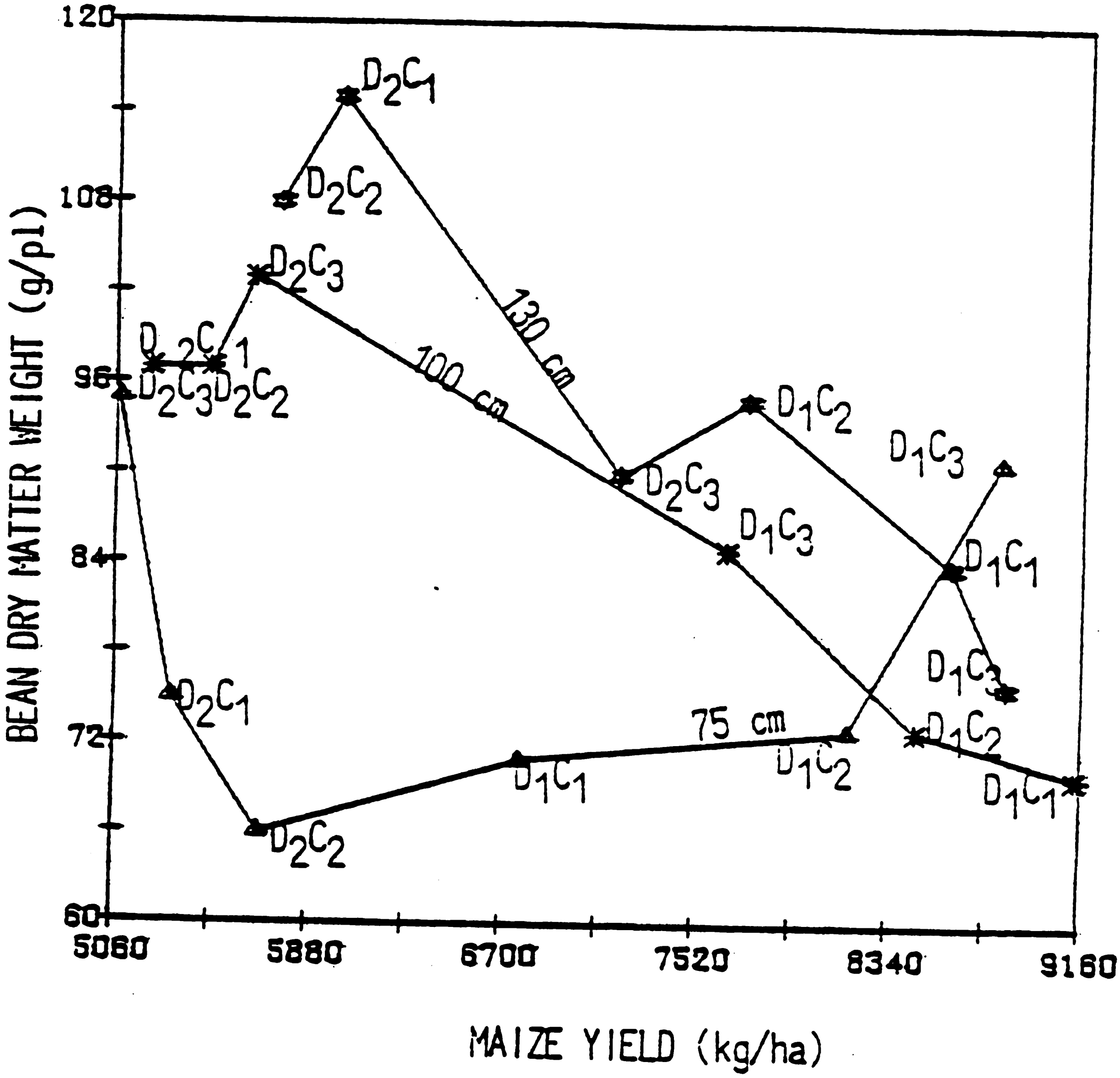
Percent protein of bean seed in maize-bean association was not different from pure stand, indicating that intercropping did not affect bean seed quality (protein). However, in associated culture, protein percent of bean seed was significantly high in high maize density. It was suggested that increased seed percent protein in associated culture was a natural consequence of a reduced seed filling rate due to reduced light intensity for photosynthesis.

As a consequence, seed yield was reduced while percent protein of bean seed was increased at the high maize density, probably because of their negative correlation type of relationship. Treatment combinations which were high in maize grain percent protein were also significantly high in bean seed yield, suggesting a low degree of inter-crop competition for available moisture, nutrients and light at the low maize density. Competition for available light has been implicated on suppressed nodule formation (97) and, consequently, N-fixation. This possibly contributed to low bean yield at the high maize density since beans could not fix nitrogen for optimum use.

Dry matter weight (Figure 3) and bean seed yield in associated culture were significantly reduced (26 to 57%, and 45 to 66%, respectively), as compared with monoculture beans. Taller and wider maize plant canopy had a competitive advantage over beans and therefore might have intercepted a greater share of light than the beans. It was suggested that light was a limiting factor for beans which might have affected the optimum utilization of other factors necessary for normal bean plant growth and production. However, harvest index was not significantly different from monoculture beans. Mann et al. (68) and Reddy et al. (79) concluded that beans suffered strong competition from the maize, principally when planted simultaneously with high maize populations. Also maize yield was not affected by the beans or a modest reduction in yield was offset by production from the minor crop (1,22).

In production point of view, maize relative yield $\frac{\text{associated culture maize yield}}{\text{monoculture maize yield}} \times 100\%$ at the low maize density was from 52 to 73% while at the high density the

Figure 3. Effect of maize density, spacing and bean configuration on maize yield and bean dry matter weight.



D_1 = Maize density (45,000 plants/ha)

D_2 = Maize density (22,500 plants/ha)

$C_1 - C_3$ = Configuration levels

relative yield ranged from 69 to 93%. In contrast, the relative bean yields were higher at the low maize density than at the high maize density, with values ranging from 44 to 55%, and 33 to 46%, respectively. Yield increase over monocropping

$$\frac{\text{combined yield (maize plus beans) in association}}{\tfrac{1}{2}\text{ maize} + \tfrac{1}{2}\text{ bean yield in pure culture}} \times 100\%$$

at the low maize density was from 4 to 31% and at the high maize density yield advantages were from 21 to 55% over the mean of monoculture crops, thus supporting one of the hypothesis of these experiments. Aiyer (5), Osiru et al. (75) and Willey et al. (101) pointed out that yields of the mixture of maize and beans, and dwarf sorghum and beans were up to 38% and 55% higher, respectively, than could be achieved by growing the component crops separately, due to a greater utilization of environmental resources, different rooting depths and their different growth cycles. Furthermore, Desir et al. (20) and Willey et al (101) indicated that the largest yield increases were achieved at the high maize and bean densities. However, a net loss in gross revenue up to 7% was obtained when maize at the high density was spaced 75 cm apart and interplanted with double rows of beans. Other treatment combinations had cash returns of up to 14% over monocropping system (Table 19). Economic Returns over monocrops = Combined economic return from asso-

$$\frac{\text{ciated culture} - \text{Combined economic returns from monoculture}}{\text{Combined economic returns from monoculture}} \times 100$$

Table 19. Productivity, Economic Returns and Protein Yield per Hectare of Maize and Bean in Associated Culture and Monoculture

Treatment Combinations			Yield in Associated Culture (kg/ha)		Combined Yield (kg/ha)	Associated Monoculture Yield (%)		Yield over Monoculture %	LER	Economic Returns $		Combined Economic Returns $	Cash Returns Over Monocrops (%)	Percent Protein		Protein Yield (kg/ha)		Total Protein Yield (kg/ha)
Spacing (cm)	Density (pl/ha)	Configurations	Maize	Beans		Maize	Beans			Maize	Beans			Maize	Beans	Maize	Beans	
		1	6780	1304	8084	69	36	21	1.06	542	665	1207	-7	9.11	26.93	618	351	969
		2	8171	1190	9361	83	33	40	1.18	654	607	1261	-3	8.12	26.15	663	311	974
75	45,000	3	8812	1529	10341	90	43	54	1.34	705	780	1485	14	8.60	26.68	758	408	1165
		1	5300	1785	7085	54	50	6	1.04	424	910	1334	2	9.24	26.10	490	466	956
		2	5676	1689	7365	58	47	10	1.06	454	861	1315	1	9.04	25.03	513	423	936
	22,500	3	5074	1893	6967	52	53	4	1.05	406	965	1371	5	9.30	26.55	472	502	974
		1	9137	1286	10423	93	36	55	1.29	731	656	1387	6	8.58	27.01	784	347	1131
		2	8464	1416	9880	86	40	47	1.26	677	722	1399	7	8.72	26.84	738	380	1118
100	45,000	3	7656	1638	9294	78	46	39	1.24	612	835	1447	11	8.78	26.26	672	430	1102
		1	5207	1882	7089	53	53	6	1.06	416	960	1376	5	9.60	25.77	500	485	985
		2	5461	1848	7309	55	52	9	1.09	437	942	1379	6	9.27	25.34	506	468	974
	22,500	3	5647	1961	7608	57	55	13	1.13	452	1000	1452	11	9.21	26.69	520	523	1043
		1	8607	1328	9935	87	37	48	1.25	688	677	1365	5	8.82	27.21	759	361	1120
		2	7738	1505	9243	79	42	38	1.21	619	767	1386	6	8.80	26.19	681	394	1075
130	45,000	3	8838	1300	10138	90	36	51	1.26	707	663	1370	5	7.73	26.11	683	399	1023
		1	6012	1835	7845	61	51	17	1.12	481	936	1417	9	9.41	26.14	566	480	1045
		2	5749	1794	7543	58	50	12	1.04	460	915	1375	5	9.10	26.08	523	468	991
	22,500	3	7200	1583	8783	73	44	31	1.18	576	807	1383	6	9.34	25.73	672	407	1079
Monobeans	200,000			3571	3571				1.00		1821	1821			25.82		922	
Monomaize	22,500		6776		6776				1.00	542		542		9.29		629		
Monomaize	45,000		9831		9831				1.00	786		786		9.24		908		

It appeared that besides personal tastes, traditions, locations, environmental factors and available capital, the price of the commodities would also play part in dictating the type of proportions and species to be used in associated culture. Hart (44) found that when beans, maize, and cassava were planted at the same time, yield and economic returns were 37% and 54% higher, respectively, from the polyculture than from the monocropping system. Francis et al. (31) indicated that increased land use efficiency and higher net income from associated culture were among the reasons why subsistence farmers with limited resources insisted on maintaining associated cropping systems.

In nutritional terms, the range of combined protein yield in a maize and bean association was from 936 to 1165 kg/ha (up to 27% higher than monoculture), being much higher than monocropping mean protein production (915 kg/ha). According to Latham (66), 65 g of protein are required daily for a 55-kg active man. Therefore, the protein from associated culture would be adequate to feed 39 to 49 men for one year

$$\frac{936\ \text{kg/ha} \times 1000\ \text{g}}{65\ \text{g} \times 365\ \text{days/year}} = 39\ \text{men};\quad \frac{1165\ \text{kg/ha} \times 1000\ \text{g}}{65\ \text{g} \times 365\ \text{days/year}} = 49\ \text{men}$$

On the other hand, if half a hectare was planted to maize and the other half to beans as monoculture, protein yield would be enough to feed only 38 men yearly. Edje et al. (23) found that the protein from the maize and dwarf beans intercrop planted early in the season was sufficient to feed

42 men for one year while monoculture produced enough protein to feed only 25 men for the same period.

2. Maize and Soyabean Association

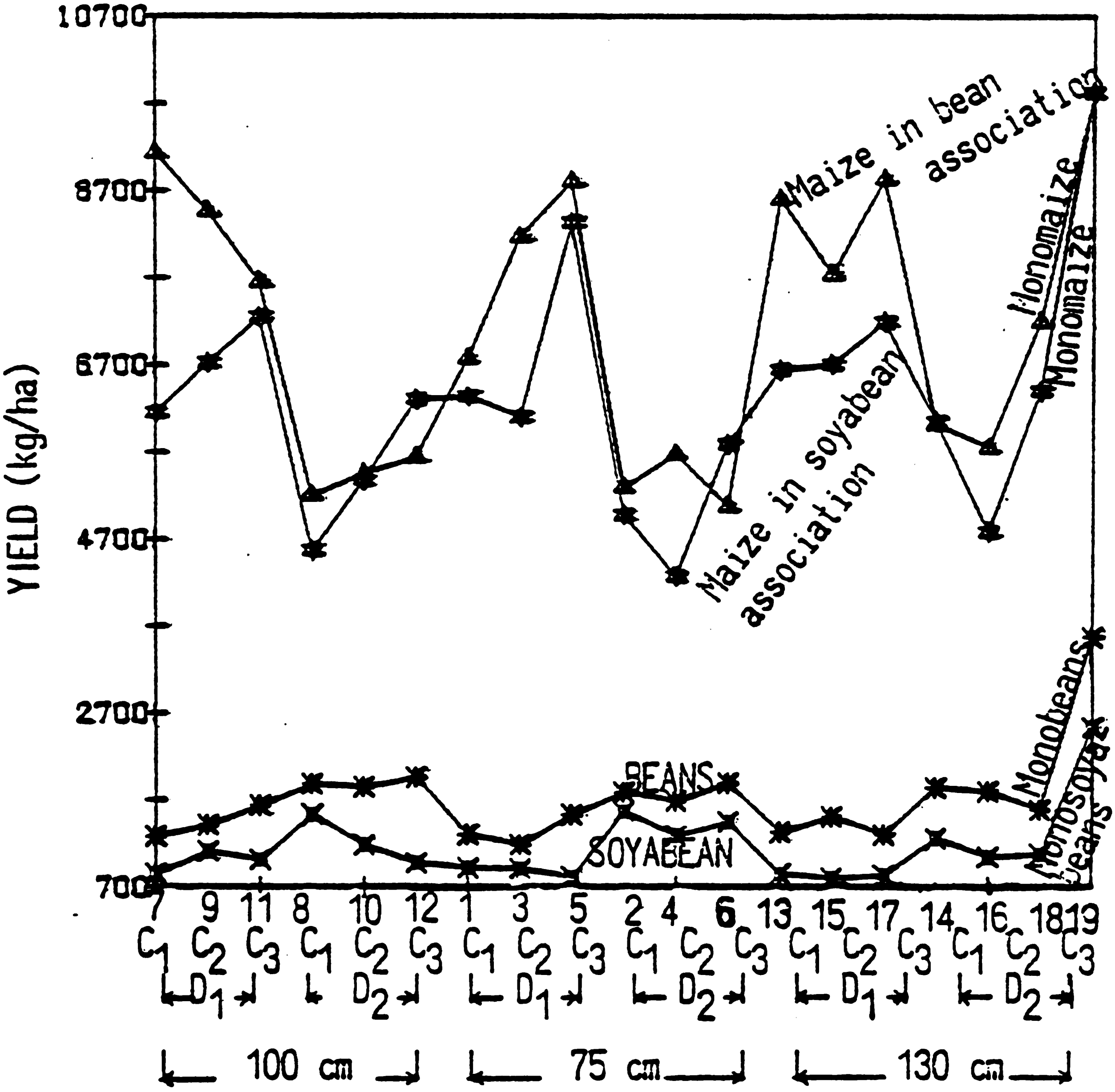
Unlike maize in association with beans, maize height in maize-soyabean association was significantly affected by soyabean configurations besides the effect of maize density. At the high maize density, the third row spacing maize height was significantly increased presumably due to the well-known effects of reduced light intensity upon internode extension. With a few exceptions, intercropped maize was shorter than pure stand maize probably due to intensive competition for available soil moisture since these crop species had similar growth cycles and were both capable of penetrating soils to a greater depth for nutrients and moisture.

Grain percent protein and 100-kernel weight were increased when low density maize with rows spaced at 130 cm was interplanted with two soyabean rows 50 cm from maize rows. This combination gave maize plants an ample root system sorption zone from which adequate nutrients and moisture were obtained for optimum rate of photosynthesis and the photosynthate was presumably transferred to the sinks (seeds) for nourishment. Percent protein of maize was significantly high at high maize density when maize rows were spaced 100 cm apart and two soyabean rows interplanted 38 cm from maize rows. It was speculated that high maize percent protein was probably due to amino acids excreted to the soil from soyabean and taken up by maize for protein synthesis. However, it appeared that the amount of amino acids released did not influence grain yield (number of kernels/cob) suggesting that those compounds were transferred to maize when the number of kernels/cob were already initiated, consequently, percent protein and 100-kernel weight in this treatment combination were significantly higher than in monoculture maize. Nevertheless, N-fixation is an energy requiring process and therefore soyabean would only fix nitrogen if its root system sorption zone was void of nitrogen. Howell (46) indicated that soyabeans and other legumes acquired work energy (550 Kcal/lb) for the symbiotic fixation of nitrogen. In spite of the high percent protein of maize, the maize protein production per hectare was lower than that obtained from the monoculture maize, that is, 6733.75 kg/ha x 9.79% protein = 659 kg/ha protein yield as compared with monoculture maize protein yield of 9831.57 kg/ha x 9.24% protein = 908 kg/ha protein production. Therefore, intercropping maize with legumes does not seem to be a solution for total maize protein production per unit area.

High density maize with soyabean rows planted 50 cm from maize rows outyielded most treatments in the associated culture, indicating that inter-crop competition for moisture, nutrients, space and available light was greatly reduced and there was probably limited root system sorption zone overlap of the component crops as compared to cases where component crop rows were only 17 cm apart. Unless roots of one species had mechanisms to avoid roots of the other species, growing two species very close would reduce yield of both crops since each species was capable of spreading its massive lateral roots or penetrating the soil to a greater depth in search of nutrients and moisture. Unlike maize-bean association, only one treatment in maize-soyabean association was not significantly different from pure culture maize, indicating that interspecific competition for moisture, nutrients and available light was quite severe in the latter association. This might possibly be due to similar growth cycle of the two crop species in which competition for natural resources was quite intensive and resulted in reduced rate of photosynthesis for both component crops. Maize and soyabean entered and terminated their grain filling period at nearly the same time. Hence there was more direct competition for light over the growth period. Effective crop combinations would depend on different grain filling periods for the two crops. Consequently, yields of maize and soyabeans were drastically reduced as compared with the yields of the former association (Figure 4). One soyabean row between maize rows 75 cm apart at the high maize density was a more efficient way of land use than the other experimental units and the best way to maximize economic returns as the following calculations indicated:

(8338 kg/ha x 8 ¢/kg) + (813 kg/ha x 22 ¢/kg soyabean) = $846

Figure 4. Maize, bean and soyabean yields in associated culture and monoculture.



D_1 = Maize density (45,000 plants/ha)
D_2 = Maize density (22,500 plants/ha)
$C_1 - C_3$ = Configuration levels

Note: Maize yield in association with soyabean was lower than in maize-bean association.

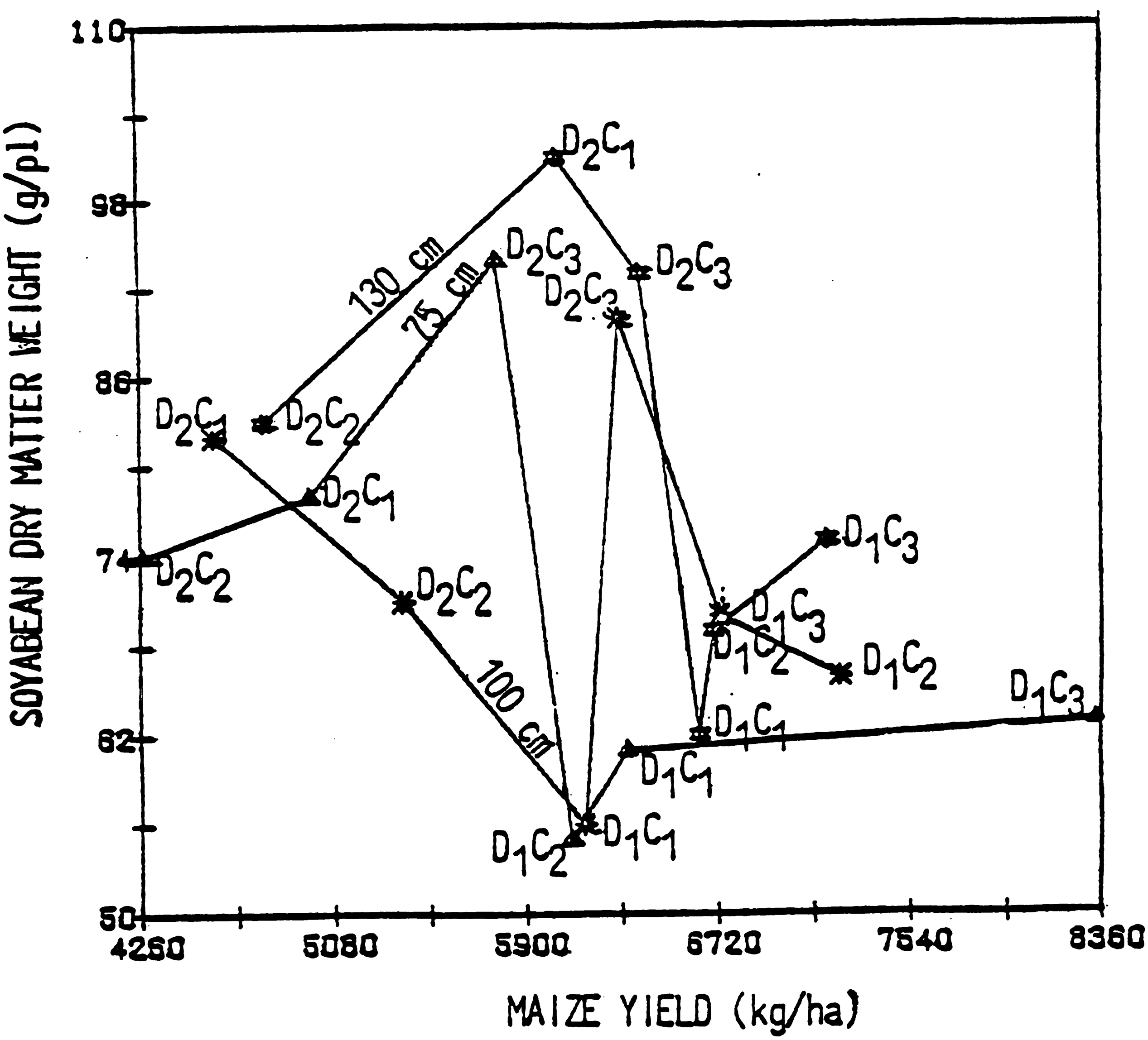
compared with pure stand maize 9831 kg/ha x 8 ¢/kg = $786 or monoculture soyabean 2535 kg/ha x 22 ¢/kg = $558. It was obvious from these calculations that farmers who practiced maize-soyabean mixture in the developing countries gained a higher cash return than could be achieved from either monoculture crops. Planting legumes in alternating single rows gave greater returns than other intercropping patterns (57) although other researchers (78, 85) found slightly higher yields of maize and soyabean when planted in alternating double or triple rather than single rows. Although soyabeans yielded more at the low maize density, the increase was not large enough to offset the maize yield losses due to reduced density. Other authors (57, 58, 85) found maize yield increase in association with soyabeans while Enyi (24) found maize yield reduction when planted in association with grain legumes.

Yield of soyabeans was too low such that the values of land equivalent ratios in maize associated with soyabeans were slightly above control (1.00). The same treatment which was not significantly different in yield from pure culture maize also gave the highest LER (1.14), although this value was not significantly different from pure stand maize.

Grain percent oil was not significantly different from pure stand maize in all combinations except one which had higher oil content than monoculture maize. In spite of the above exception, it was generally concluded that intercropping had no effect on the quality of maize (protein and oil), but was quite effective in reducing the quantity (yield) of one or both component crops. About 6% of the total energy stored by the maize plant is used for oil and protein synthesis (46) and thus reduced rate of photosynthesis in associated culture could not severely affect these components.

Soyabean nodes per plant, branches per plant, pods per plant and dry matter weight (Figure 5) were significantly higher at the low maize than at the high maize density because of more space and thus less inter-crop competition for environmental factors. Probably there was less competition within the root surface and root system sorption zones for nutrients and moisture than in high maize density. As a result, the rate of nutrient uptake and photosynthesis was accelerated and soyabean plants obtained their optimum carbohydrates for their normal growth and development of the soyabean components. It was found that branches in associated culture were reduced from 60 to 98%, pods per plant were reduced from 45 to 74% and dry matter weight was reduced from 40 to 67% as compared with monoculture soyabean, presumably due to reduced photosynthetic rate. Galal et al. (36) found that pod number and seed number per plant were about 30 to 50% more in solid soyabeans than in associated culture. Oizumi (74) noted that emergence of soyabean branches depended mainly on the content of available carbohydrates in the plants while N content did not seem to be a limiting factor.

Figure 5. Effect of maize density, spacing and soyabean configuration on maize yield and soyabean dry matter weight.



D_1 = Maize density (45,000 plants/ha)

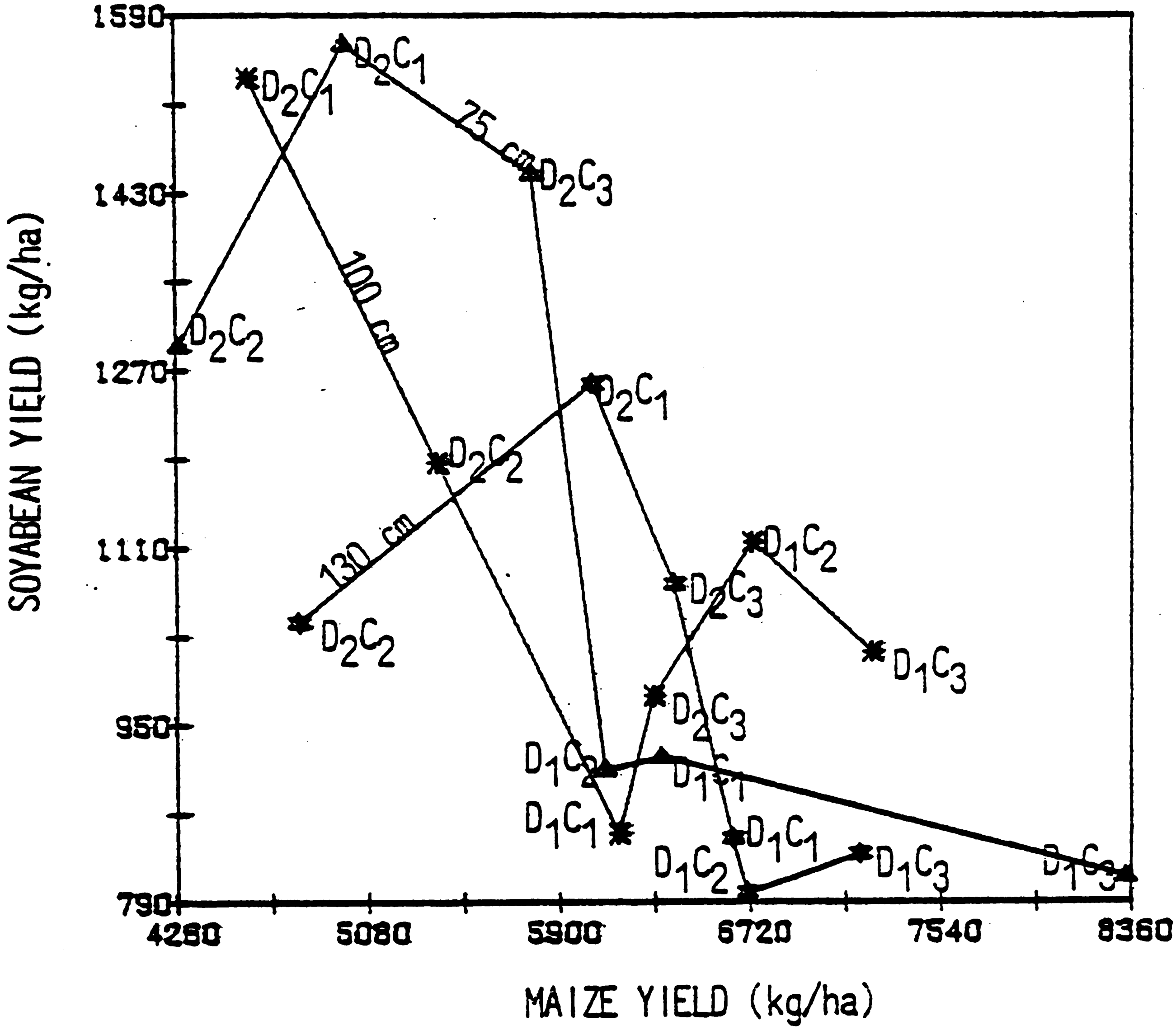
D_2 = Maize density (22,500 plants/ha)

C_1 - C_3 = Configuration levels

Soyabean yield as in previous traits was also high at the low maize density (Figure 6) for the same reasons presented earlier. Soyabean at the low maize density with maize rows spaced 75 cm apart yielded significantly higher than other row widths except the second maize row spacing at the low maize density. Soyabean yield reduction due to intercropping was from 38 to 68%. Contrary to soyabean yield, soyabean seed percent protein was significantly high at the high maize density. However, it appeared that increased protein was actually a consequence of reduced yield per plant particularly in treatments with soyabean rows planted as close as 17 or 25 cm away from maize rows. Comparison with monoculture soyabean protein indicated an increase in percent protein of soyabean seed from the intercropping systems. Galal et al. (36) in Egypt found an increase in soyabean percent protein when soyabeans were associated with maize.

Weight per 100-seed and seed percent oil were generally high when soyabean rows were planted far away from maize rows, probably due to increased rate of photosynthesis. However, 100-seed weight was not significantly different from control while percent oil was significantly lower than sole crop, thus justifying one of the hypothesis of this experiment. Seed percent oil reduction was from 3 to 7% while Wahua (96) found 3% less oil in soyabean seed intercropped with sorghum. Son et al. (86) found that plant height and protein content of soyabeans in association with

Figure 6. Effect of maize density, spacing and soyabean configuration on maize and soyabean yields.



D_1 = Maize density (45,000 plants/ha)
D_2 = Maize density (22,500 plants/ha)
$C_1 - C_3$ = Configuration levels

Note: D_1C_3 of 75 cm row spacing provided the best combination for land use efficiency, combined yield and net income.

sorghum increased while branch number, number of pods per plant, seed yield, 100-seed weight and oil content decreased as compared with monoculture soyabeans.

Since maize-soyabean association was severely affected by intensive intra and interspecific competition for available nutrients, moisture and solar energy, relative yields of maize ranged only from 43 to 65% and 62 to 85%, at the low and the high maize density, respectively. Likewise, the relative soyabean yield range was only from 38 to 62% at the low maize density, and 31 to 44% at the high maize density (Figure 8). Despite the low relative values at the high density, combined yield increase over pure stand was from 13 to 48%, indicating more efficient use of natural resources. Besides three treatments which had combined yield lower than the mean yield of monoculture crops, other combinations at the low maize density had higher yields (up to 21%) than the mean of the pure culture crops. This yield response phenomenon is quite common wherever intercropping is practiced because farmers do not plant crops at their optimum densities. In order to achieve the benefits of intercropping systems, component crops should be planted at their recommended densities.

Economic loss of up to 9% was obtained as a result of low density, further stressing that the subsistence farmer could not only lose combined yield per hectare but could also diminish his cash returns. However, other treatment combinations at the low maize density had gross revenue returns

Table 20. Productivity, Economic Returns and Protein Yield per Hectare of Maize and Soyabean in Associated Culture and Monoculture

Treatment Combinations: Spacing (cm)	Density (pl/ha)	Configurations	Yield in Associated Culture (kg/ha): Maize	Beans	Combined Yield (kg/ha)	Associated / Monoculture Yield (%): Maize	Soyabeans	Yield over Monoculture (%)	LER	Economic Returns $: Maize	Soyabeans	Combined Economic Returns $	Cash Returns Over Monocrops (%)	Percent Protein: Maize	Soyabeans	Protein Yield (kg/ha): Maize	Soyabeans	Total Protein Yield (kg/ha)
		1	6339	921	7260	64	36	17	.98	507	203	710	6	8.94	38.31	567	353	920
		2	6100	909	7009	62	36	13	.95	488	200	688	2	8.25	38.24	503	348	851
75	45,000	3	8338	813	9151	85	32	48	1.14	667	179	846	26	8.81	37.49	734	305	1039
		1	4985	1564	6549	51	62	6	1.08	399	344	743	10	8.85	37.93	441	593	1034
		2	4272	1291	5563	43	51	-10	.92	342	280	622	-7	9.13	38.16	390	493	883
	22,500	3	5788	1447	7235	59	57	17	1.13	463	318	781	16	9.59	36.41	555	527	1082
		1	6157	852	7009	63	34	13	.94	492	187	679	1	8.47	38.24	521	326	847
		2	6734	1115	7849	68	44	27	1.10	539	245	784	17	9.79	37.53	659	418	1077
100	45,000	3	7249	1016	8265	74	40	34	1.10	580	223	803	19	8.92	37.55	647	381	1028
		1	4574	1534	6108	46	60	-1	1.02	366	337	703	5	8.82	37.78	403	579	982
		2	5381	1187	6568	55	47	6	.98	430	261	691	3	9.31	37.82	501	449	950
	22,500	3	6310	977	7287	64	38	18	.99	505	215	720	7	9.32	36.24	588	354	942
		1	6645	848	7493	67	33	21	.98	531	186	717	7	8.21	38.78	545	329	874
		2	6708	799	7507	68	31	21	.98	537	176	713	6	8.39	38.29	563	306	869
130	45,000	3	7192	834	8026	73	33	30	1.06	575	183	758	13	8.58	38.49	617	321	938
		1	6046	1258	7304	61	50	18	1.08	484	277	761	13	9.18	37.23	555	468	1023
		2	4783	1043	5826	49	41	-6	.87	383	229	612	-9	2.29	37.58	444	392	836
	22,500	3	6398	1077	7475	65	42	21	1.04	512	237	749	11	9.34	37.13	597	400	997
Monosoyabeans	300,000			2535	2535				1.00		558	558			36.19		917	
Monomaize	22,500		6776		6776				1.00	542		542		9.30		630		
Monomaize	45,000		9831		9831				1.00	786		786		9.24		908		

of up to 16% and 1 to 26% cash returns were obtained at the high maize density. Nevertheless, densities did not seem to affect total protein production per hectare, probably because protein content of each species changed with the change in maize density being generally high at the high maize density for soyabeans and vice versa for percent protein of maize.

Eight hundred thirty-six to 1082 kg/ha combined protein yield from the maize and soyabean association which was up to 18% higher than monoculture, would be sufficient to feed 35 to 46 men for one year while half a hectare each of a pure culture of maize and soyabeans produced enough protein to feed only 38 men for one year. Maize at the high density paced 75 cm apart and interplanted with a single row of beans or soyabeans, constantly provided high values of yield, LER, gross revenue returns and combined protein yield, possibly because this combination permitted more efficient use of land and intercepted most of the available light. It appeared that the root system sorption zone in this treatment combination was probably adequate to support the crop species.

In maize-bean association, it was found that each of the spacings had at least one combination which was not significantly different in yield performance as compared with monoculture maize while in maize-soyabean association only one combination at 75 cm row width was nearly as good as pure stand maize. It was therefore suggested that among the maize row spacings, 130 cm row width was more convenient in the developing countries in conducting cultural operations such as hand weeding, spraying, fertilizer application (to maize) and harvesting of minor crops. On the other hand, 75 cm row width had merits over the other spacings in that it suppressed weeds earlier in the growing season but was deficient in providing opportunities for other cultural practices. Highlights from these experiments suggested that possibly by growing maize at 45,000, 50,000, 55,000 and 60,000 plants/ha and intercropped with both 50 and 100% legume densities would provide opportunities to detect the optimum maize-bean or soyabean combinations for yield. However, in terms of gross revenue returns, it appeared that the present maize-bean association proportion would still be more profitable than the above proposal if beans and maize prices would remain at 4:1 ratio, respectively (31). Legumes are capable of compensating for available spacing by increasing the number of branches per plant while maize is incapable.

SUMMARY AND CONCLUSION

Maize-bean association at the high density was significantly taller than maize at the low density probably due to reduced light intensity which might have stimulated IAA activity in promoting internode extension through the alteration of IAA oxidase inhibitor, leading to increased maize height. However, maize 100-kernel weight and percent protein of maize were significantly high at the low maize density probably because each plant simply has had greater opportunity to photosynthesize and to store carbohydrates and nitrogen assimilates temporarily for use later in seed filling. Increased 100-kernel weight and percent protein of maize might also be a consequence of the early bean maturity which occurred at about the grain filling stage of maize.

Furthermore, there was also a probability that high percent protein of maize might be attributed to nitrogen released from beans to maize through nodule exudation and decomposition of bean leaves and nodules. Nevertheless, it was felt that both fixed and residue nitrogen would significantly contribute to succeeding non-legume crops. At any rate, percent protein of maize in maize-bean association was not significantly different from pure culture except two treatments which were significantly lower than the control.

Percent oil of maize in maize associated with dry beans was not significantly different from pure stand maize, indicating that association of these component crops did not affect maize quality (protein and oil). When maize at the high density was spaced 100 and 130 cm apart and interplanted with double bean rows and 75 cm row width with a single bean row, maize yield was not significantly different from monoculture maize, indicating that any bean yield obtained from these combinations was a bonus in land management for the subsistence farmers in combined yield for food and net income and that is why subsistence farmers engage themselves in associated culture. However, besides the above treatment combinations, the rest of the treatments yielded significantly lower than monoculture maize and their yield reductions were from 7 to 48%. The yield losses were much lower than in maize associated with soyabeans in which yield reductions ranged from 26 to 56%, presumably due to early maturity of dry beans and therefore more moisture and nutrients were available for maize grain filling in maize-bean association. On the other hand, maize and soyabean had longer growth cycle. They entered and terminated their grain filling period at nearly the same time. Consequently, there was more direct competition for light and moisture over the growth period. It was concluded that effective crop combinations would depend on different grain filling periods for the two crops.

Land equivalent ratio (LER) values of 1.21 to 1.34 were highly significant undoubtedly due to more complete use of available nutrients and light in associated culture. It was concluded that up to 1.34 hectares of monocrops would be required to produce the equivalent yield of one hectare of the crops in association. Maize at the high density spaced 75 cm apart and interplanted with a single dry bean row gave the best intercropping combination in terms of more efficient use of land and natural resources, yield, combined protein yield and cash returns. However, at the current bean and maize prices, a farmer would be economically better by growing dry beans as pure culture rather than engaging himself in associated culture.

Dry bean height was not significantly affected by intercropping, indicating that probably San Fernando plants completed their vegetative cycle before maize was vigorous enough to impose inter-crop competition for available nutrients and light. The partial shading at that time was probably not severe enough to significantly promote bean plant internode elongation in associated culture to cause a difference in plant height as compared with the monoculture bean height. Number of nodes per bean plant was significantly higher in low maize density than in high maize density probably due to ample space for branch development, nutrients, moisture and solar energy. Comparison with monoculture beans showed that some treatments had less nodes per bean plant than the control while their plant heights were not significantly different, supporting the commonly accepted concept that height was not only a function of nodes per plant but also a function of internode length. There was a 31 to 64% branch reduction of beans in associated culture as compared with pure culture beans.

Number of racemes and pods per plant in associated culture were 24 to 51% and 30 to 60% lower, respectively, than pure stand bean values, the reduction being highest at the high maize density. It was concluded that these traits coincided with vigorous maize vegetative growth cycle which imposed severe inter-crop competition for available nutrients, moisture and light. Bean 100-seed weight in associated culture was as low as 14% (depending on maize density) as compared with pure stand beans. Percent protein in bean seed in associated culture was not significantly different from monoculture, indicating that associated culture did not affect San Fernando seed quality. Dry matter weight and seed yield in associated culture were significantly lower than the pure culture beans and they were 26 to 57% and 45 to 66% lower, respectively, than monoculture bean values, being more drastically reduced at the high maize density. However, the harvest index was not significantly different from the monoculture beans.

Observations on maize in association with soyabeans indicated that most intercropped maize was significantly shorter than monoculture maize undoubtedly due to severe inter-crop competition for available moisture. When maize at the low density was spaced 130 cm apart and double soyabean rows were planted 50 cm from maize rows, 100-kernel weight was significantly increased probably due to higher levels of photosynthesis as a result of ample light intensity and root system sorption zone from which adequate resources were obtained and ultimately higher levels of photosynthate were probably stored and were later transferred to the sinks. However, the actual kernel weight would certainly depend on how many kernels had to be filled per plant or per unit area.

Percent protein of maize was significantly higher in associated culture than in pure stand when maize at the high density was planted 100 cm apart and two soyabean rows were planted 38 cm from maize rows. It was speculated that high percent protein of maize was probably due to amino acids excreted to the soil by bean nodules, roots and stems and taken up by maize for protein synthesis. However, it appeared that the amount of amino acids released did not influence grain yield (number of kernels/cob) suggesting that these compounds were available for maize use when the number of kernels per plant were already initiated. Consequently, percent protein and 100-kernel weight of maize were significantly higher in this treatment combination than in monoculture maize.

A single treatment combination maize at the high density with rows spaced 75 cm apart and interplanted with a single soyabean row was not significantly different from monoculture maize yield. It was therefore concluded that interspecific competition for available moisture, nutrients and solar energy was more critical in maize-soyabean association than when maize was associated with beans, possibly due to similar growth period of maize and soyabeans. The grand mean difference between maize yield in association with beans and maize associated with soyabeans (7107-6330 kg/ha) was 777 kg, indicating an intensive maize-soyabean competition probably for moisture.

The highest LER obtained in maize associated with soyabean was 1.14 as compared with 1.34 in maize-bean association, further stressing the intensive intra and inter-crop competition. At any rate, the LER obtained in maize-soyabean association was not significantly different from pure stand maize (1.00). Percent oil of maize was not significantly different from the control in all combinations except one which had higher percent oil than the monoculture maize.

Number of branches and pods per soyabean plant in associated culture were 60 to 98% and 45 to 74% lower, respectively, while dry matter weight was 40 to 67% lower (depending on maize density) than monoculture soyabean. Soyabean yield was significantly high at the low maize density with rows spaced at 75 cm apart.

Soyabean was 38 to 68% lower in seed yield than the monocropping of soyabean. There was a significant increase in percent protein in soyabean seed in associated culture as a consequence of reduced yield per plant, a non-significant change in 100-seed weight and a significantly lower percent oil of soyabean seed than in monoculture soyabeans.

In general, performance of these experiments indicated that the maize relative yield at the low maize density was from 52 to 73% while at the high density it ranged from 69 to 93%. Likewise, relative yields of maize in association with soyabeans ranged from 43 to 65% and 62 to 85%, at the low and the high maize density, respectively. In contrast, the relative bean yields were higher at the low maize density than at the high density, with values ranging from 44 to 55%, and 33 to 46%, respectively. Similarly, soyabean relative yield range was from 38 to 62% at the low maize density, and 31 to 44% at the high maize density.

In maize-bean association, yield increase over monocropping at the low maize density was from 4 to 31% while at the high density yield advantages were from 21 to 55%. On the other hand, combined yield increase over monoculture was from 13 to 48% when maize at the high density was planted in association with soyabeans. Maize-bean gross revenue returns at the high maize density ranged from a loss of 7% to an increase of up to 14% while at the low maize density, an increase of economic returns of 1 to 11% was obtained. Unlike maize-bean association, maize-soyabean cash values ranged from a loss of 9% to an increase of up to 16% and 1 to 26% at the low and the high maize densities, respectively. Combined protein yield from a maize and bean association was from 936 to 1165 kg/ha (up to 27%) while maize-soyabean association provided a combined protein yield ranging from 836 to 1082 kg/ha (up to 18%) as compared with their monoculture component crops mean protein production of 915 and 912 kg/ha, respectively. The protein was adequate to feed up to 49 and 46 men for one year, respectively, as compared with pure culture where protein was sufficient to feed only 38 men for the same period. Maize at the high density spaced 75 cm apart and interplanted with a single legume row constantly provided higher values of land use efficiency (LER), yield, gross revenue returns and combined protein yield per hectare than any other treatment combinations or monocrops.

For the general field management, it was noted that 130 cm row width was more convenient in the developing countries than the other spacings in conducting cultural operations such as hand weeding, spraying, fertilizer application and harvesting of minor crops. On the other hand, 75 cm row width had merits over the other spacings in that it suppressed weeds earlier in the growing season but was deficient in providing opportunities for other cultural practices.

Although beans and soyabeans in these experiments might have influenced percent protein of maize to a certain degree, it appeared that their organic matter and fixed nitrogen would be a more important source of nitrogen for the succeeding maize crop. Optimum density, adequate soil nutrients and moisture should be maintained in the associated culture in order to maximize land use efficiency (LER), combined yield and protein production, and economic returns. Identification of compatible crop species for intercropping should get the first priority in the future research in order to utilize the limited natural resources more efficiently and to improve combined yield production for the subsistence farmer. Results obtained in these experiments gave some highlights which suggested that the best maize-legume combinations would be detected if both 50 and 100% bean or soyabean densities would be interplanted with maize at 45,000, 50,000, 55,000 and 60,000 plants/ha. Legumes are capable of compensating for available space by increasing the number of branches per plant while maize is incapable.

APPENDICIES

APPENDIX A

Crop Science Field Lab Rainfall Data (Mt. Hope and Beaumont Roads, East Lansing, Michigan)

Inches of Rain per Month

Year	April	May	June	July	August	September	October	Total
1978	1.81	2.74	2.83	1.73	3.17	4.38	2.68	19.34
1977	4.18	.34	4.79	3.49	2.19	6.39	2.06	23.44
1976	4.52	3.01	4.26	4.84	.56	1.85	2.79	21.83
1975	5.45	2.75	2.59	2.99	8.25	2.69	1.18	25.90
1974	2.04	4.64	1.74	1.53	3.88	2.76	1.11	17.70
1973	3.94	4.98	3.66	.87	2.24	3.28	2.20	21.16
1972	3.36	2.94	2.38	2.47	3.50	4.20	3.10	21.95
1971	1.28	1.67	3.95	3.22	1.67	3.04	1.08	15.91
1970	6.24	2.32	6.45	6.68	1.81	4.15	3.41	31.06
1969	4.37	3.22	4.35	7.44	.43	2.28	2.08	24.17
1968	1.72	4.41	9.15	2.15	2.66	3.61	1.25	24.95
1967	3.53	1.18	6.11	1.63	3.45	2.48	3.26	21.64
1966	3.18	2.09	3.99	2.33	3.21	1.70	1.02	17.52
1965	.75	1.26	2.62	.77	3.75	5.11	1.15	15.41
1964	2.86	4.46	3.69	2.04	4.20	1.94	.08	19.27
1963	1.95	2.24	4.38	2.56	2.66	2.17	.30	16.26
1962	1.09	2.02	3.55	2.30	2.00	1.68	2.62	15.26
17 Year Average	3.07	2.72	4.15	2.88	2.92	3.16	1.85	20.75

Compiled By M. B. Tesar

APPENDIX B

Maize yield per hectare in association with beans.

TREATMENTS				REPLICATIONS				
No.	Spacing	Distance of bean rows from maize rows	Maize density (pl/ha)	I	II	III	IV	MEAN (kg/ha)
1	75cm	2 rows 17cm away	45,000	6604	6604	7033	6879	6780
2		2 rows 17cm away	22,500	5002	5537	4895	5764	5300
3		2 rows 25cm away	45,000	6348	7842	9104	9388	8171
4		2 rows 25cm away	22,500	5153	6802	5059	5691	5676
5		1 row 37.5cm away	45,000	7902	9682	8711	8953	8812
6		1 row 37.5cm away	22,500	4835	5244	5137	5079	5074
7	100cm	2 rows 25cm away	45,000	9052	9335	9630	8532	9137
8		2 rows 25cm away	22,500	5375	5010	5275	5167	5206
9		2 rows 38cm away	45,000	9557	7237	10087	6972	8463
10		2 rows 38cm away	22,500	5065	5467	5947	5362	5460
11		1 row 50cm away	45,000	7313	7507	7580	8220	7656
12		1 row 50cm away	22,500	4660	5660	6027	6242	5647
13	130cm	2 rows 25cm away	45,000	6517	7661	12188	8058	8606
14		2 rows 25cm away	22,500	6050	6785	5264	5947	6011
15		2 rows 38cm away	45,000	7347	6691	9958	6955	7738
16		2 rows 38cm away	22,500	4941	6603	6220	5232	5749
17		2 rows 50cm away	45,000	8470	7123	10141	9617	8838
18		2 rows 50cm away	22,500	8623	7982	6197	5997	7200
19	75cm	Monocropping maize	22,500	6993	8013	6323	5773	6776
20	75cm	Monocropping maize	45,000	10997	8564	9986	9777	9831

APPENDIX C

Maize grain percent protein in association with beans.

TREATMENTS No.	Spacing	Distance of bean rows from maize rows	Maize density (pl/ha)	REPLICATIONS I	II	III	IV	MEAN (%)
1	75cm	2 rows 17cm away	45,000	9.07	8.14	9.12	10.13	9.11
2		2 rows 17cm away	22,500	9.73	9.40	8.31	9.51	9.24
3		2 rows 25cm away	45,000	7.81	8.07	8.71	7.89	8.12
4		2 rows 25cm away	22,500	9.42	8.15	9.22	9.37	9.04
5		1 row 37.5cm away	45,000	9.08	8.13	8.75	8.44	8.60
6		1 row 37.5cm away	22,500	9.65	9.20	9.61	8.74	9.30
7	100cm	2 rows 25cm away	45,000	8.79	8.32	8.48	8.72	8.58
8		2 rows 25cm away	22,500	9.65	8.78	10.35	9.64	9.60
9		2 rows 38cm away	45,000	8.86	7.78	9.07	9.17	8.72
10		2 rows 38cm away	22,500	9.25	9.38	9.42	9.02	9.27
11		1 row 50cm away	45,000	8.85	8.54	8.80	8.92	8.78
12		1 row 50cm away	22,500	9.45	8.98	9.35	9.08	9.21
13	130cm	2 rows 25cm away	45,000	9.29	8.12	8.93	9.05	8.85
14		2 rows 25cm away	22,500	9.23	9.07	9.77	9.56	9.41
15		2 rows 38cm away	45,000	8.68	8.49	8.58	9.44	8.80
16		2 rows 38cm away	22,500	9.16	9.36	9.06	8.82	9.10
17		2 rows 50cm away	45,000	7.31	7.38	8.04	8.18	7.73
18		2 rows 50cm away	22,500	9.43	9.10	9.17	9.68	9.34
19	75cm	Monocropping maize	22,500	9.29	8.05	9.44	10.38	9.29
20	75cm	Monocropping maize	45,000	9.06	9.47	9.14	9.31	9.24

APPENDIX D

Maize grain percent oil in association with beans.

No.	Spacing	Distance of bean rows from maize rows	Maize density (pl/ha)	REPLICATIONS I	II	III	IV	MEAN (%)
1	75cm	2 rows 17cm away	45,000	3.95	4.03	4.07	3.86	3.98
2		2 rows 17cm away	22,500	3.90	4.11	4.14	4.02	4.00
3		2 rows 25cm away	45,000	4.08	4.01	4.01	4.41	4.13
4		2 rows 25cm away	22,500	3.98	4.05	3.96	4.02	4.00
5		1 row 37.5cm away	45,000	4.12	4.06	4.05	4.10	4.08
6		1 row 37.5cm away	22,500	3.91	4.14	4.05	4.46	4.14
7	100cm	2 rows 25cm away	45,000	4.00	4.09	4.05	4.03	4.04
8		2 rows 25cm away	22,500	3.89	4.04	3.76	4.00	3.92
9		2 rows 38cm away	45,000	4.07	4.05	3.97	4.14	4.06
10		2 rows 38cm away	22,500	3.91	3.81	3.97	4.09	3.94
11		1 row 50cm away	45,000	3.76	3.73	4.05	4.02	3.89
12		1 row 50cm away	22,500	4.13	4.24	4.14	3.91	4.10
13	130cm	2 rows 25cm away	45,000	3.92	3.98	3.91	4.16	3.99
14		2 rows 25cm away	22,500	3.93	3.89	4.06	4.08	3.98
15		2 rows 38cm away	45,000	3.89	3.88	4.18	4.04	4.00
16		2 rows 38cm away	22,500	3.93	3.95	4.09	4.01	3.99
17		2 rows 50cm away	45,000	3.88	3.95	4.19	4.16	4.04
18		2 rows 50cm away	22,500	3.81	4.02	4.08	3.85	3.94
19	75cm	Monocropping maize	22,500	3.68	3.91	3.99	3.93	3.88
20	75cm	Monocropping maize	45,000	3.95	3.90	4.12	3.97	3.98

APPENDIX E

Bean yield per hectare in association with maize

TREATMENTS No.	Spacing	Distance of bean rows from maize rows	Maize density (pl/ha)	REPLICATIONS I	II	III	IV	MEAN (kg/ha)
1	75cm	2 rows 17cm away	45,000	1117	911	1696	1492	1304
2		2 rows 17cm away	22,500	1813	1822	1520	1985	1785
3		2 rows 25cm away	45,000	1064	1303	1311	1083	1190
4		2 rows 25cm away	22,500	1526	1849	1531	1849	1689
5		1 row 37.5cm away	45,000	1784	1521	1474	1338	1529
6		1 row 37.5cm away	22,500	2133	1796	2180	1464	1893
7	100cm	2 rows 25cm away	45,000	1402	1228	1143	1371	1286
8		2 rows 25cm away	22,500	2113	1575	2218	1619	1881
9		2 rows 38cm away	45,000	1554	1085	1635	1387	1415
10		2 rows 38cm away	22,500	2216	1678	2092	1407	1848
11		1 row 50cm away	45,000	1324	1593	1700	1934	1637
12		1 row 50cm away	22,500	2036	1732	2191	1885	1961
13	130cm	2 rows 25cm away	45,000	1486	939	1471	1416	1328
14		2 rows 25cm away	22,500	2065	1580	1980	1715	1835
15		2 rows 38cm away	45,000	1341	1335	1797	1548	1505
16		2 rows 38cm away	22,500	1924	1758	1750	1741	1793
17		2 rows 50cm away	45,000	1211	1109	1483	1397	1300
18		2 rows 50cm away	22,500	1778	1413	1642	1498	1583
19	50cm	Sole crop bean	200,000	3323	3569	3468	3923	3571

APPENDIX F

Bean seed percent protein in association with maize.

TREATMENT No.	Spacing	Distance of bean rows from maize row	Maize density (pl/ha)	REPLICATIONS I	II	III	IV	MEAN (%)
1	75cm	2 rows 17cm away	45,000	27.75	27.26	26.49	26.22	26.93
2		2 rows 17cm away	22,500	26.13	26.44	26.01	25.81	26.10
3		2 rows 25cm away	45,000	24.02	26.26	28.87	25.45	26.15
4		2 rows 25cm away	22,500	25.25	24.45	25.33	25.11	25.03
5		1 row 37.5cm away	45,000	27.88	26.41	27.58	24.84	26.68
6		1 row 37.5cm away	22,500	25.52	27.17	26.97	26.54	26.55
7	100cm	2 rows 25cm away	45,000	28.35	26.52	26.81	26.36	27.01
8		2 rows 25cm away	22,500	25.27	25.15	27.10	25.57	25.77
9		2 rows 38cm away	45,000	26.48	26.34	27.31	27.25	26.84
10		2 rows 38cm away	22,500	25.08	24.44	26.59	24.95	25.26
11		1 row 50cm away	45,000	27.20	24.43	26.70	26.73	26.26
12		1 row 50cm away	22,500	27.94	24.97	27.26	26.58	26.69
13	130cm	2 rows 25cm away	45,000	27.04	27.21	26.69	27.92	27.21
14		2 rows 25cm away	22,500	26.07	25.11	27.11	26.27	26.14
15		2 rows 38cm away	45,000	24.20	26.42	27.03	27.10	26.19
16		2 rows 38cm away	22,500	23.48	27.30	27.03	26.53	26.08
17		2 rows 50cm away	45,000	27.16	25.08	26.03	26.19	26.11
18		2 rows 50cm away	22,500	27.16	24.40	26.06	25.32	25.73
19	50cm	Sole Crop bean	200,000	25.70	26.20	25.59	25.78	25.82

APPENDIX G

Maize-Bean Land equivalent ratios (LER).

TREATMENT No.	Spacing	Distance of bean rows from maize rows	Maize density (pl/ha)	REPLICATIONS I	II	III	IV	MEAN
1	75cm	2 rows 17cm away	45,000	.94	1.03	1.19	1.08	1.06
2		2 rows 17cm away	22,500	1.00	1.16	.93	1.09	1.04
3		2 rows 25cm away	45,000	.90	1.28	1.29	1.24	1.18
4		2 rows 25cm away	22,500	.93	1.31	.95	1.05	1.06
5		1 row 37.5cm away	45,000	1.25	1.56	1.30	1.26	1.34
6		1 row 37.5cm away	22,500	1.08	1.11	1.14	.89	1.05
7	100cm	2 rows 25cm away	45,000	1.24	1.43	1.29	1.22	1.29
8		2 rows 25cm away	22,500	1.12	1.03	1.17	.94	1.06
9		2 rows 38cm away	45,000	1.34	1.15	1.48	1.07	1.26
10		2 rows 38cm away	22,500	1.13	1.11	1.20	.91	1.09
11		1 row 50cm away	45,000	1.06	1.32	1.25	1.33	1.24
12		1 row 50cm away	22,500	1.04	1.15	1.23	1.12	1.13
13	130cm	2 rows 25cm away	45,000	1.04	1.16	1.64	1.18	1.25
14		2 rows 25cm away	22,500	1.17	1.23	1.10	1.04	1.13
15		2 rows 38cm away	45,000	1.07	1.15	1.51	1.11	1.21
16		2 rows 38cm away	22,500	1.03	1.26	1.13	.98	1.10
17		2 rows 50cm away	45,000	1.13	1.14	1.44	1.34	1.26
18		2 rows 50cm away	22,500	1.32	1.33	1.09	.99	1.18
19	75cm	Monocropping maize	45,000	1.00	1.00	1.00	1.00	1.00
20	50cm	Sole crop beans	200,000	1.00	1.00	1.00	1.00	1.00

APPENDIX H

Maize yield per hectare in association with soyabean.

No.	Spacing	Distance of soyabean rows from maize rows	Maize density (pl/ha)	REPLICATIONS I	II	III	IV	MEAN (kg/ha)
1	75cm	2 rows 17cm away	45,000	6033	5011	7884	6428	6339
2		2 rows 17cm away	22,500	4684	4144	6268	4842	4984
3		2 rows 25cm away	45,000	6073	7204	4837	6286	6100
4		2 rows 25cm away	22,500	3700	5277	4528	3582	4272
5		1 row 37.5cm away	45,000	10431	7673	6153	9095	8338
6		1 row 37.5cm away	22,500	3024	8151	6748	5226	5787
7	100cm	2 rows 25cm away	45,000	4640	5462	6607	7917	6156
8		2 rows 25cm away	22,500	4085	4437	5025	4750	4574
9		2 rows 38cm away	45,000	5710	8355	7370	5500	6733
10		2 rows 38cm away	22,500	4070	5642	6607	5205	5381
11		1 row 50cm away	45,000	7950	5832	7012	8203	7249
12		1 row 50cm away	22,500	6930	5575	6657	6077	6310
13	130cm	2 rows 25cm away	45,000	5388	5170	7923	8097	6644
14		2 rows 25cm away	22,500	6341	6617	5579	5644	6045
15		2 rows 38cm away	45,000	6238	8267	5664	6661	6708
16		2 rows 38cm away	22,500	3520	5179	4467	5964	4783
17		2 rows 50cm away	45,000	4947	9017	6476	8326	7191
18		2 rows 50cm away	22,500	6776	6376	6873	5567	6398
19	75cm	Monocropping maize	22,500	6993	8013	6326	5773	6776
20	75cm	Monocropping maize	45,000	10997	8564	9986	9777	9831

APPENDIX I

Maize grain percent protein in association with soyabean.

TREATMENT No.	Spacing	Distance of soyabean rows from maize rows	Maize density (pl/ha)	REPLICATIONS I	II	III	IV	MEAN (%)
1	75cm	2 rows 17cm away	45,000	8.88	8.89	8.93	9.05	8.94
2		2 rows 17cm away	22,500	8.93	8.81	8.85	8.83	8.85
3		2 rows 25cm away	45,000	8.22	8.26	8.26	8.28	8.25
4		2 rows 25cm away	22,500	9.06	9.12	9.01	9.33	9.13
5		1 row 37.5cm away	45,000	8.85	8.63	8.48	9.30	8.81
6		1 row 37.5cm away	22,500	9.56	9.65	9.62	9.55	9.59
7	100cm	2 rows 25cm away	45,000	8.55	8.43	8.34	8.57	8.47
8		2 rows 25cm away	22,500	8.82	8.72	8.73	9.01	8.82
9		2 rows 38cm away	45,000	9.71	9.74	9.84	9.84	9.79
10		2 rows 38cm away	22,500	9.30	9.34	9.23	9.36	9.31
11		1 row 50cm away	45,000	9.21	8.31	8.92	9.23	8.92
12		1 row 50cm away	22,500	9.67	9.25	9.19	9.17	9.32
13	130cm	2 rows 25cm away	45,000	8.20	8.18	8.14	8.34	8.21
14		2 rows 25cm away	22,500	8.97	9.06	9.23	9.47	9.18
15		2 rows 38cm away	45,000	8.45	8.28	8.26	8.56	8.39
16		2 rows 38cm away	22,500	9.19	9.23	9.53	9.23	9.29
17		2 rows 50cm away	45,000	8.60	8.59	8.63	8.50	8.58
18		2 rows 50cm away	22,500	9.32	9.24	9.22	9.60	9.34
19	75cm	Monocropping maize	22,500	9.30	8.07	9.34	10.50	9.30
20	75cm	Monocropping maize	45,000	9.01	9.57	9.16	9.24	9.24

APPENDIX J

MAIZE GRAIN PERCENT OIL IN ASSOCIATION WITH SOYABEAN

TREATMENT No.	Spacing	Distance of soyabean rows from maize rows	Maize density (pl/ha)	REPLICATIONS I	II	III	IV	MEAN (%)
1	75cm	2 rows 17cm away	45,000	4.13	4.09	4.01	4.07	4.07
2		2 rows 17cm away	22,500	4.22	4.18	4.17	4.16	4.18
3		2 rows 25cm away	45,000	4.03	4.05	4.02	3.96	4.01
4		2 rows 25cm away	22,500	4.06	4.02	4.12	3.85	4.01
5		1 row 37.5cm away	45,000	4.22	4.19	4.05	4.05	4.13
6		1 row 37.5cm away	22,500	4.12	3.92	3.85	3.87	3.94
7	100cm	2 rows 25cm away	45,000	4.00	3.77	4.03	4.01	3.95
8		2 rows 25cm away	22,500	4.12	4.15	4.10	4.00	4.09
9		2 rows 38cm away	45,000	4.01	3.91	3.88	3.86	3.91
10		2 rows 38cm away	22,500	4.11	4.05	4.00	3.82	3.99
11		1 row 50cm away	45,000	4.22	4.01	4.14	3.99	4.09
12		1 row 50cm away	22,500	3.97	4.03	3.93	3.88	3.95
13	130cm	2 rows 25cm away	45,000	4.04	4.07	3.99	3.88	3.99
14		2 rows 25cm away	22,500	4.01	3.92	3.98	3.98	3.97
15		2 rows 38cm away	45,000	4.13	4.01	3.98	3.99	4.03
16		2 rows 38cm away	22,500	4.17	4.15	3.88	4.03	4.06
17		2 rows 50cm away	45,000	4.10	4.22	4.04	4.14	4.12
18		2 rows 50cm away	22,500	4.02	3.98	4.11	3.94	4.01
19	75cm	Monocropping maize	22,500	3.75	3.96	4.04	3.97	3.93
20	75cm	Monocropping maize	45,000	4.12	3.89	4.06	4.01	4.02

APPENDIX K

Soyabean seed yield per hectare in association with maize.

TREATMENT No.	Spacing	Distance of soyabean rows from maize rows	Maize density (pl/ha)	REPLICATIONS I	II	III	IV	MEAN (kg/ha)
1	75cm	2 rows 17cm away	45,000	1043	1033	843	763	920
2		2 rows 17cm away	22,500	1240	1700	1423	1893	1564
3		2 rows 25cm away	45,000	866	766	1133	870	909
4		2 rows 25cm away	22,500	1166	1570	1306	1123	1291
5		1 row 37.5cm away	45,000	846	513	666	1226	813
6		1 row 37.5cm away	22,500	1676	1400	1306	1406	1447
7	100cm	2 rows 25cm away	45,000	850	680	1055	825	852
8		2 rows 25cm away	22,500	1415	1265	1935	1520	1533
9		2 rows 38cm away	45,000	900	1000	975	1585	1115
10		2 rows 38cm away	22,500	1060	960	1165	1565	1187
11		1 row 50cm away	45,000	1150	650	950	1315	1016
12		1 row 50cm away	22,500	1000	955	1110	845	977
13	130cm	2 rows 25cm away	45,000	735	655	1035	964	847
14		2 rows 25cm away	22,500	1147	1117	1238	1529	1258
15		2 rows 38cm away	45,000	794	764	691	947	799
16		2 rows 38cm away	22,500	1011	794	988	1376	1042
17		2 rows 50cm away	45,000	582	735	764	1255	834
18		2 rows 50cm away	22,500	1076	826	958	1447	1077
19	75cm	Sole crop soyabean	300,000	3000	2333	2943	1862	2535

APPENDIX L

Soyabean seed percent protein in association with maize.

TREATMENT No.	Spacing	Distance of soyabean rows from maize rows	Maize density (pl/ha)	REPLICATIONS I	II	III	IV	MEAN (%)
1	75cm	2 rows 17cm away	45,000	39.73	37.36	39.29	36.88	38.31
2		2 rows 17cm away	22,500	38.46	38.97	37.70	36.61	37.93
3		2 rows 25cm away	45,000	39.07	36.86	37.68	39.34	38.24
4		2 rows 25cm away	22,500	38.78	36.76	38.63	38.47	38.16
5		1 row 37.5cm away	45,000	36.88	37.40	39.55	36.15	37.49
6		1 row 37.5cm away	22,500	35.66	36.68	36.48	36.82	36.41
7	100cm	2 rows 25cm away	45,000	38.56	39.47	35.56	39.36	38.24
8		2 rows 25cm away	22,500	39.02	38.60	36.53	36.98	37.78
9		2 rows 38cm away	45,000	39.64	36.44	36.94	37.09	37.53
10		2 rows 38cm away	22,500	37.40	37.61	38.56	37.90	37.87
11		1 row 50cm away	45,000	36.84	39.90	36.49	36.97	37.55
12		1 row 50cm away	22,500	34.80	37.17	36.17	36.82	36.24
13	130cm	2 rows 25cm away	45,000	38.87	38.17	39.59	38.49	38.78
14		2 rows 25cm away	22,500	37.74	36.83	37.58	36.78	37.23
15		2 rows 38cm away	45,000	39.29	36.78	38.53	38.58	38.29
16		2 rows 38cm away	22,500	38.56	37.75	38.25	35.78	37.58
17		2 rows 50cm away	45,000	39.91	37.83	38.88	37.35	38.49
18		2 rows 50cm away	22,500	37.13	36.90	37.79	36.70	37.13
19	75cm	Sole crop soyabean	300,000	35.84	36.58	36.02	36.34	36.19

APPENDIX M

Sovabean seed percent oil in association with maize.

No.	Spacing	Distance of soyabean rows from maize rows	Maize density (pl/ha)	REPLICATIONS I	II	III	IV	MEAN (%)
1	75cm	2 rows 17cm away	45,000	18.20	19.12	18.19	19.01	18.63
2		2 rows 17cm away	22,500	18.94	18.26	18.60	18.86	18.66
3		2 rows 25cm away	45,000	18.30	18.95	18.35	17.89	18.37
4		2 rows 25cm away	22,500	18.71	18.63	18.35	18.63	18.58
5		1 row 37.5cm away	45,000	18.31	19.11	18.12	18.80	18.58
6		1 row 37.5cm away	22,500	19.06	18.72	18.79	18.88	18.86
7	100cm	2 rows 25cm away	45,000	18.16	18.12	19.16	18.43	18.47
8		2 rows 25cm away	22,500	18.50	18.48	19.36	18.82	18.79
9		2 rows 38cm away	45,000	17.98	19.12	18.65	18.21	18.49
10		2 rows 38cm away	22,500	18.40	18.65	18.49	18.82	18.59
11		1 row 50cm away	45,000	18.56	17.96	18.80	18.05	18.34
12		1 row 50cm away	22,500	19.53	18.57	18.80	18.43	18.83
13	130cm	2 rows 25cm away	45,000	18.40	17.81	18.47	17.93	18.15
14		2 rows 25cm away	22,500	18.65	18.79	18.85	19.11	18.85
15		2 rows 38cm away	45,000	17.96	19.21	18.38	18.23	18.44
16		2 rows 38cm away	22,500	18.25	18.89	18.33	19.10	18.64
17		2 rows 50cm away	45,000	17.70	18.60	18.92	18.72	18.48
18		2 rows 50cm away	22,500	18.48	19.27	18.71	18.84	18.82
19	75cm	Sole crop soyabean	300,000	19.35	19.62	19.84	19.33	19.53

APPENDIX N

Maize-Soyabean Land equivalent ratios (LER).

TREATMENT				REPLICATIONS				
No.	Spa-cing	Distance of soyabean rows from maize rows	Maize density (pl/ha)	I	II	III	IV	MEAN (%)
1	75cm	2 rows 17cm away	45,000	.90	1.03	1.08	.93	.98
2		2 rows 17cm away	22,500	.84	1.21	1.11	1.17	1.08
3		2 rows 25cm away	45,000	.84	1.17	.87	.95	.96
4		2 rows 25cm away	22,500	.72	1.29	.90	.77	.92
5		1 row 37.5cm away	45,000	1.23	1.11	.84	1.35	1.14
6		1 row 37.5cm away	22,500	.83	1.55	1.12	1.04	1.13
7	100cm	2 rows 25cm away	45,000	.70	.93	1.02	1.10	.94
8		2 rows 25cm away	22,500	.84	1.06	1.16	1.03	1.02
9		2 rows 38cm away	45,000	.82	1.40	1.07	1.13	1.10
10		2 rows 38cm away	22,500	.72	1.07	1.06	1.09	.98
11		1 row 50cm away	45,000	1.11	.96	1.02	1.31	1.10
12		1 row 50cm away	22,500	.96	1.06	1.04	.92	.99
13	130cm	2 rows 25cm away	45,000	.73	.88	1.14	1.17	.98
14		2 rows 25cm away	22,500	.96	1.25	.98	1.12	1.08
15		2 rows 38cm away	45,000	.83	1.29	.80	1.02	.98
16		2 rows 38cm away	22,500	.66	.94	.78	1.10	.87
17		2 rows 50cm away	45,000	.64	1.37	.91	1.31	1.06
18		2 rows 50cm away	22,500	.97	1.10	1.01	1.09	1.04
19	75cm	Monocropping maize	45,000	1.00	1.00	1.00	1.00	1.00
20	75cm	Sole crop soyabean	300,000	1.00	1.00	1.00	1.00	1.00

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