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Legume-Maize Intercropping System: An Alternative Pathway for Sustainable Agriculture

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Intercropping provides ample scope to include two or more crops simultaneously in same piece of land thus targeting higher productivity from unit area on sustainable basis. Maize, a cereal crop of immense importance, planted in wide rows offers the possibility for adoption of intercropping. The intercropping system with maize and legume is beneficial in multiple aspects. The success of maize-legume intercropping system largely depends on choice of crops and their maturity, density, and time of planting. Advantage of maize-legume intercropping system is promoted in the form of higher yield and greater utilization of available resources, benefits in weeds control [1,2], pests and disease management [3], fixation of biological nitrogen by legumes and transfer of N to associated maize [4,5], insurance against crop failure to small holders, and control of erosion by covering a large extent of ground area [6]. Though maize-legume intercropping system exhibits limitations like less scope of farm mechanization, dependence on more human workforce, and chance of achieving less productivity from maize, the system implies more advantages for small holders in developing countries where human workforce is not a constraint.

Keywords: Intercropping; legume; maize; productivity; sustainability.

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1. INTRODUCTION

The intercropping system is raising of two or more crops simultaneously in the same piece of land [7,8]. Intercropping of maize with grain legumes can be practical and beneficial on small farms (less than 2 hectares): on large, commercial farms intercropping makes mechanized procedures such as weeding and application of fertilizer or pesticides more difficult and so it tends not be used. The objective of land preparation under a conventional tillage system is to produce a seedbed that is weed-free, with aerated soil into which water can percolate and in which maize seeds can have close contact with the soil, and from which the seedling can emerge easily [9]. This can be achieved by hand using a hand-hoe, or with a plough and sometimes also a harrow pulled by oxen or a tractor. Soon after harvesting, weeds should be slashed and ploughed or dug into the soil so they can start to rot down and release their nutrients. Any crop residues present can also be incorporated into the soil at this stage. To preparing a conventional seed bed manually, about 8-10 days of manual labour per hectare is needed. Too fine a seed bed, especially on sandy soils, leaves the plot vulnerable to wind erosion. A coarser tilth reduces the risk of wind eroding the soil but still allows water to infiltrate. Clod sizes should be about 6 cm or less and the soil should be cultivated to a depth of 15-30 cm. Unless farmers have access to expert local advice on conservation agriculture (no or minimal tillage) and access to and knowledge about the use of inputs such as herbicides, they would be better advised to practice conventional tillage. Higher yields are achieved when the intercrops have different rooting systems, a different pattern of water and nutrient demand, and a different above ground growth habit. This results in more efficient use of water, nutrient and sunlight. Many grain legumes meet these criteria and are therefore suitable for intercropping with maize [10]. Intercropping should be practiced in areas with soil and climatic conditions that meet the requirements of both maize and legumes as indicated in Table 1. The choice of the legume intercrop should be based on local recommendations which are adjusted to the agro-ecological conditions, growing season crop and local demand [11].

Spatial arrangement of maize and legume is critical in determining the growth, yield of intercrops and other benefits accruing from intercropping. Intercrop planting arrangements involve the replacement of maize with the legume so that overall maize plant population decreases. Other arrangements are additive ones, wherein the maize is maintained at recommended population density as in the sole crop and the legume incorporated in between.

Table 1. Climatic and soil requirements of selected maize-legume intercropping systems

Type of intercropping system	Altitude (masl)	Rainfall (mm)	Ideal temp. N/D (min. max.)	Soils
Maize-bean	800-1,800	700-1500 mm	10-30°C	Well-drained loams, moderate to high fertility pH 5-7.5
Maize– soybean	900-1,500	700-1500mm	20-30°C	Well-drained sandy clay loams, moderate to high fertility pH 4.8-7
Maize– groundnut	900 -1,500	250-650 mm in 3-4 months or 650-1,300 mm in 4-5 months	20-30°C	Well-drained, light sandy soils, pH 5.2-6.5
Maize– cowpea	500 -1,500	400 -900 mm	20-30°C	Well-drained, heavy to light sandy soils moderate to high fertility pH 4.8–7
Maize–pigeonpea	900 -1,500	800–1,000 mm	20-30°C	Well drained, sandy clay loam soil, moderate to high fertility, pH 4.8–7 (for maize) Pigeon pea can tolerate saline soils

Row intercropping– Growing maize and a legume in well-defined rows. Sometimes the plant population for the two crops can be close to that found in sole crops. For example, maize is planted at its recommended planting density, but every-other row is shifted to provide a wider alternate inter-row for legume. This arrangement works best where peak nutrient demands and duration to maturity for the two crops differ. A good example is maize-bean, in which maize and beans are planted in alternate rows, and the spacing of maize is close to that found in sole crops (e.g. spaced at 75 cm between rows, 50 cm within rows, 2 plants per hole).

Strip intercropping– Growing maize and legume in strips wide enough to permit independent cultivation but narrow enough for the crops to interact. This plant arrangement permits more light to reach the shorter legume. Legumes that benefit from this arrangement include groundnut, soybean, common bean and cowpea. In strip cropping the maize plant population may be lower than in sole crops but similar yields can be achieved. A good example is the MBILI system: two rows of maize alternating with two rows of legume. This arrangement gives better yields and is more profitable than row intercropping. It requires less labour and gives better increase in yield on application of modest amounts of fertilizer.

Mixed intercropping– Traditional practice where maize and a legume are grown together in no distinct row arrangements.

Relay intercropping–Planting legume into a standing crop of maize. The purpose is to avoid the legume smothering effect on young maize plants and to reduce competition compared to planting at the same times. For good yields, the rainfall distribution should allow for adequate moisture during peak growth periods and dry periods during harvesting of both crops. A good example is sowing of cowpea about 6 weeks after the maize. This practice will certify that the faster growing cowpea does not smother maize plants. In case of drought, there are prime chances that cowpea will give some yield even if maize fails.

Within row intercropping– Growing maize and legumes in alternate planting positions within rows. A good example is the additive mixed intercrop design for maize-pigeon pea intercrop. The maize seed is planted at wider positions, which helps to accommodate pigeon pea plants in between. This arrangement gives the same maize plant population as when maize is evenly spaced within the row, but gives space for planting a legume intercrop. Perhaps surprisingly, the yield of maize when grown in these clusters of three plants can be the same as if the same number of plants is spaced individually i.e. the competition effect on the maize is minimal. Seed for OPV maize and legumes can be purchased from registered dealers every season or can be purchased once then subsequent crops for the next 2-3 seasons can be grown from saved seed. If farmers are planning to save seed from the current crop, undesirable plants should be rogued out before harvesting. To ensure a high germination percentage, seed should be saved only from healthy plants and threshing should be done carefully to avoid damaging seed. For crops like soybean and bean, threshing can be done soon after harvesting and seed stored for use in the next season. For groundnut, seed should be stored in pods and then removed from pods by hand about 1-2 weeks before planting. If threshing before storing, seed should be cleaned by removing damaged seed and other material, such as stones. For groundnuts, immature, mouldy and small pods should be removed before storing seed. Seed should be stored separately from grain to be used for food, in a dry area that is well ventilated.

1.1 Germination Test

A germination test can be a useful guide to how many seeds should be sown to get the desired plant population. The test gives an idea of how many 'normal' seedlings can be expected from a given number of seeds. About 50 to 100 seeds can be sown onto a seedbed. The seedbed should be kept moist. The number of normal seedlings that emerge in about 5-7 days should be counted and % germination calculated:

> (Number of seeds germinated/number seeds sown) x 100 = % germination

Alternatively, the test can be done in the house. For this, 50 to 100 seeds of the selected maize variety are placed between moist newspaper sheets. The paper with the seeds is placed in a safe area where neither children nor animals can disturb it. The paper and seeds are kept moist. After four days of incubation, count the number of seeds that have germinated and express it as a percentage. If germination rate is over 95%, the number of seeds sown can be same as the desired plant population as most of the seeds planted will emerge. But if germination is 80%, on average only 4 of the 5 seeds planted will emerge. Therefore, to get the desired plant population, number of seeds planted should be increased by 25%. If the germination percentage is 50%, it means out of the 2 planted, on average only one will emerge. In such a case it is advisable to double the seed rate. Factors that need to be taken into account with regard to sowing maize seed are:

Quality seed: Only plump, undamaged seed should be sown; shrivelled or damaged seed should be discarded. Maize seed should be sown in moist but not waterlogged soil, when the soil moisture has reached at least 30 cm deep. The normal recommendation for spacing of monocrop maize is 75 cm between rows with 50 cm between planting stations and 2 plants per planting hole. This gives a plant population of about 53,333 plants per hectare. In drier areas, with less than 500 mm rainfall during the growing season, the spacing between rows and plants should be increased, thus provides a lower plant population.

Maize-common bean intercrop: Maize is planted at the same spacing as for maize monocrop and the beans are planted in rows between the maize rows. The number of maize plants per hectare is therefore the same as for mono-cropped maize.

Maize-pigeon pea intercrop: Maize is planted with 75 cm between rows and 75 cm between planting stations, with three plants per planting station. Clusters of 3 pigeon peas plants (medium to late maturing varieties) are planted within the row, between each maize planting station. This gives the same number of maize plants per hectare as for mono-cropped maize.

MBILI system: In this system two rows of maize are planted with a row spacing of 50 cm with a one metre gap before the next pair of maize rows and in-between, two rows of legumes are planted, as cowpea or common bean. The spacing within the row for maize is 50 cm. This arrangement gives the same number of maize plants per hectare as for mono-cropped maize. If the germination rate is above 95% then the number of seeds per planting station should be the same as the target plant population. To achieve a plant density of 53,333 plants per hectare requires between 20-25 kg maize seed per hectare, assuming germination rate above 95%: if the germination test shows a lower rate of germination, more seed will be needed, for example, if the germination rate is 50%, the number of seeds per planting station should be doubled.

Ideally, farmers should use fertilizer at optimum rates in their local area. This should be based on knowledge of the nutrients present in the soil and of local agricultural practices, such as intercropping with suitable legumes and incorporation of manure and crop residues into the soil, and also on expected returns to investments. Very often, such optimum recommendations are not available. In this case, some blanket recommendations are provided below. The aim of these recommendations is not to maximise production; rather it is to increase yields from around 1 tonne of maize grain per hectare, or even less, up to as much as 6 tonnes per hectare (Table 2). Although even larger yields than this are possible, and commonly achieved on large-scale commercial farms in developed countries, the aim here is to increase yields in a cost-effective way that is likely to be within the reach of small holder farmers. The recommendations are intended primarily for use when improved varieties are being grown: it is less likely to be cost effective to use fertilizer on traditional varieties.

The basal fertilizer should be placed in the bottom of the planting hole and covered with a little soil. The seed is then planted on top at the right depth the seed and fertilizer must not touch as this can damage the seed. The hole is then covered with more soil. Before the top-dressing is applied, or at the same time, the plot should be weeded so the fertilizer benefits the maize not the weeds. The top-dressing fertilizer should be applied when the maize is knee-high (45-60 cm tall). In soaring rainfall areas (>1000 mm) and

Table 2. Average current and achievable yields in maize-legume systems with satisfactory seed, fertilizer and congenial agronomic practices

Crop	Yield under traditional system (t/ ha)	Potential yield with adoption of good agricultural practices (t/ ha)
Maize	0.5-1.2 or less	1.5-6
Legume	0.5 or less	1-3

where soils are sandy, top dressing of fertilizers is recommended in two equal splits, at 3 and 6 weeks after germination. Either fertilizer can be applied in a circle around each plant or along the row; in both cases the fertilizer should be applied about 10 to 15 cm away from the base of the plants. The fertilizer should not be allowed to touch the plants. It should be covered with soil, for example by hoeing. Farmers need to think carefully before they decide to top dress their maize crop as they could be wasting their money. Topdressing can lead to increased yields, but only if the crop is developing well under favourable climatic conditions; increased yields can then be profitable if good crop prices are expected. The value of the expected increase in yield should be at least twice the total cost related to fertilizer use. If the crop has developed poorly because of poor rainfall and/or the price of maize is expected to be low, top dressing can be cancelled and the fertilizer set aside for the next planting season. When available, livestock manure can be an important resource for improving maize yields. Applying manure together with mineral fertilizers gives better yields than using either manure or fertilizer alone. Other than N and P, manure also contains potassium, calcium and magnesium in addition to other nutrients. These nutrients become available to plants as the manure decomposes. Apart from contributing to improved soil fertility, manure also:

- Improves soil structure, soil aeration, soil water infiltration rate and soil water-holding capacity
- If soil is acidic, it helps to reduce soil acidity–this improves the capacity of the soil to store nutrients.

These attributes make well-decomposed manure a key resource in low production systems across the country, particularly on sandy soils. However, these manures contain diminished amount of nutrients compared to mineral fertilizers: For example, 100 kg of farmyard manure (FYM) contain about 1 kg of N and 0.8 kg of P (1.8 kg P_2O_5); in analogy, 100 kg of the mineral fertilizer urea contains 46 kg of N, and 100 kg of DAP contains about 18 kg N and 22 kg P (46 kg P_2O_5). If the same amounts of nutrients provided by mineral fertilizers were to be supplied only by farmyard manure, the farmer need to apply 5-10 tonnes per hectare. So, for every tonne of farmyard manure applied per hectare, the amount of urea can be reduced by 12 kg per hectare in the first year after manure application, 6 kg in the second year and 3 kg in the third year. There is a wide range of organic inputs other than FYM that are used by farmers for soil fertility management. These include:

- Cereal residues, viz: Maize Stover. These residues have low nutrient contents: they do not have as much N as legume residues and take longer to decompose and release nutrients.
- Legume residues, viz: soybean, cowpea and groundnut residues. These residues have plenty N and take less time to decompose than cereal residues.
- Organic inputs derived from nitrogen-fixing trees or green manure crops, which generally have relatively high N contents and release nutrients in the short term.

2. CONCLUSION

So considering the priority of maize across the globe, production sustainability is of prime importance. Being an exhaustive crop in nature that requires ample nutrient inputs to achieve the target yields, sole cultivation of maize may create further depletion of soil nutrients causing a negative impact to production potential. In this glance, maize-legume intercropping system is considered a viable option as it has tremendous potential to replenish the soil nutrients, produce enhanced yields and economic benefit by utilizing limited resource, limits the damage caused by pests, diseases and weeds to a great extent, control soil erosion by covering ground and provide natural insurance and security to small land holders under risky conditions against total crop failure. Thus, in substantial impression, maize-legume intercropping system can improve the yield as well as production sustainability of the system.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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