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ECONOMIC ASSESSMENT OF CEREAL - LEGUME INTERCROPPING SYSTEM, A WAY FORWARD FOR IMPROVING PRODUCTIVITY AND SUSTAINING SOIL HEALTH

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ABSTRACT

Intercropping, the agricultural practice which include growing two or more than two crops at the same time that leads to the reduction of the weeds competition, lowering the insect attacks and fertilizer losses. This crop mixture greatly influenced the yield of crops due to the different root pattern, plant height, canopy structure and different nutrient, water and light requirements based on the complementary utilization of these resources by the component crop. Intercropping while using legumes enhance the fertility level of the soil through biological nitrogen fixation (BNF), it conserves the soil by providing greater ground cover, also improves soil physical conditions, soil structure and texture. Moreover, intercropping provides insurance against the failure of crop especially in the area with more uncertain conditions about drought, frost and flood. So, it provides more financial stability then sole cropping pattern, this feature makes the intercropping suitable mainly at small farms. It also needs lower inputs through fewer requirements of fertilizers so intercropping is an environmentally friendly technique. Besides this intercropping also have some disadvantages. Selection of best intercropping system is quite complex because the success of the system totally dependent on the interaction of crops, available resources their management and the environmental conditions. Intercropping is also very helpful for

increasing the yield of subsequent crop. This paper provides knowledge about the evaluation of intercropping and crop combinations it also elaborates the advantages and disadvantages of intercropping by using a large number of examples from the literature which shows the importance of intercropping for the sustainable agriculture.

Keywords: Biological nitrogen fixation, intercropping, crop mixture, sustainable agriculture, crop combination

INTRODUCTION

The concept of cereal legume intercropping is not in vogue in agricultural sciences **[1]**. Presently, Intercropping is highly beneficial for the small land holding farmers as it can fulfill their daily needs. Its popularity is increasing day by day due to the advantage of sustainable yield of two or more crops as compare to the mono cropping technique **[2]**. Soil texture and soil fertility can be enhanced through legume- cereal intercropping technique **(Figure 1)**. Long term rotation of the grain legumes intercropping play an important role in high yield **[3]**.

Among intercropped plants species there are various interactions can be found like commensalisms and amensalism, proto cooperation, mixed perennial forage crop, mixed relay intercrop of red clover (*Trifoliumpratense* L.) into winter wheat, strip relay intercropping of corn (Zea mays L.) and cereal rye (*Secalecereale* L.), etc **(Figure 2)**. As legumes are famous for their nitrogen fixation behavior that will help in the improvement of soil texture, soil organic matter content and sustainable yield of the crops **[4]**. Legumes nitrogen fixation can also be used as a field management tool for better crop growth enhancement tool **[5]**. Yield of the crop is directly linked with the nitrogen fixation legumes crops **[6]**.

Figure 1: A relay mixed intercrop of red clover after winter wheat harvest [33]

Figure 2: Examples of intercropping in (a) mixed perennial forage crop; (b) mixed relay intercrop of red clover (*Trifolium pratense* L.) into winter wheat (*Triticum aestivum* L.); and (c) strip relay intercropping of corn (*Zea mays* L.) and cereal rye (*Secalecereale* L.) [33]

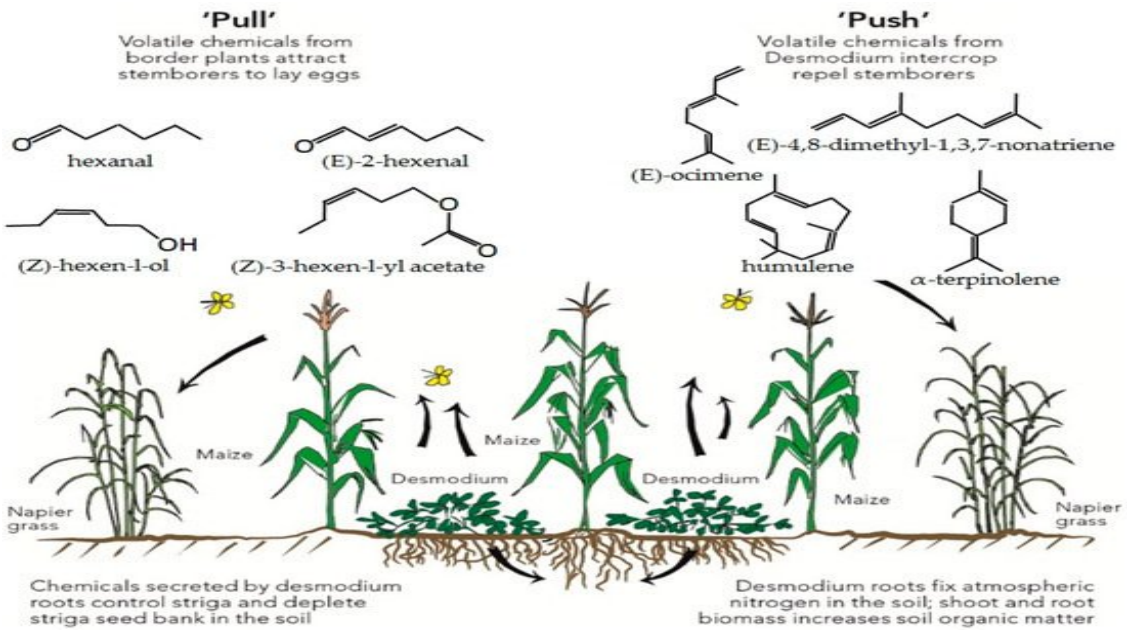

Figure 3: Scheme developed by the African Insect Science for Food and Health at the International Centre of Insect Physiology and Ecology (ICIPE) of the push-pull system in corn which illustrates the semiochemical ecology of attracting or detracting the corn stem borer and suppressing weeds. Used with permission from ICIPE [33]

Legumes intercropping factors knowledge can enable farmers to increase the efficiency of the N_2 fixation. In the Legumes-cereals intercropping system pigeonpea + maize is the highly sustainable yield and use nutrient efficiently while for maximum resource use efficiency groundnut + pigeon (legume + legume intercropping system) pea is considered to be efficient one **[7]**. The soil health which is very important to farmer is also enhanced by this system of crop rotation or legume intercropping. For instance **Figure 3** illustrated the strip intercropping method involves planting corn (the cash crop), a "pull" crop, like Napier grass (*Pennisetumpurpureum Schumach*.) that uses

semiochemicals to attract corn stem borers, and a "push" crop like the legume *Desmodium* spp. planted between rows to repel corn stem borers from the corn. Nitrogen fixation is the important factor in the increasing soil fertilizer content and production of the crop as legumes have greater capability to fix un-used residual nitrogen present in the soil to the plants **[8]**.

Hayat **[9]** found that after beans with phosphorus application grain yield of wheat was increased by 20% over sorghum. Likewise, wheat growth, development and yield differ significantly when followed after mung bean crop as compared to fallow reported by Asim **[10]**. The source and fate of N in wheat cropping system trial, evaluated by Wood **[11]**, established in 1983 at ICARDA IN Syria. They reported that yield of wheat grown continuously were considerably less than when grown in rotation with chickpea, lentil or a fallow. Recovery of N fertilizer in wheat (9-26%) and in the soil (26%) was low; indicating that up to 50% of the fertilizer may have been lost from the soil-plant system. Detailed N^{15} studies indicated that ammonia volatilization and denitrification were likely to be the major N loss mechanism. Uptake of N in wheat grain was greater than then input from fertilizer.

ECONOMIC EVALUATION OF INTERCROPPING

Arif and Malik **[12]** have studied 10 different inter-cropping patterns for analyses in 3 consecutive year from 2003 till 2006 in 3 different locations of Pothwarplateau of Pakistan which were a blend of low, medium and high rainfall patterns rain fed circumstance. In comparison to all other pattern the legume establish the uppermost percentage for soil moisture (9.06-13.41%) at each locality the most beneficial cost benefit ratio in elevated rainfall area was recorded in sunflower + mung bean (2.79) as well as fallow-wheat (2.90) legumes based intercropping designs. In intermediate and little rainfall conditions, groundnut based and fallow-wheat cropping designs verified mostly remunerative and well-organized the highest net and gross benefits for mung bean + sunflower based cropping scheme in high rainfall areas were of (Rs.54077.00/ha and 34738.00 / ha, respectively).The profit was at its peak in groundnut based cropping for moderate and poor rain fed regions, the marginal rate of reoccurrence were considerably higher in canola based cropping designs at almost all locations .

However in high and low rain fed Areas the marginal degrees of return were best in fallow wheat cropping seasons Same

is the case with marginal degrees, net return, cost benefits ratio were well evident in canola + groundnut almost every locations of rain fed areas. In soybean + maize – sarson cabbage system it was evident the highest system productivity 25.2/ha each day profitability system profitability (Rs 141.3 / ha each day^{-}). More over cowpea + maize and cabbage sarson system (22.9 kg / ha each day and Rs 126.1 per ha each day).

The balance sheet of nitrogen fixations was at its maximum in maize + soybean, cabbage + sarson as this sequence is with cowpea+ maize and cabbage + sarson sequence. Incorporation of 50% RDF in kharif crops show most gain in nitrogen as per balance sheet same with the combine treatment of 50% organics + 50 % NPK revealed the lowest gain **[12]**. According to Rajput **[13]** inter cropping between pigeon pea (*Cajanus cajan*) and soybean with a ratio of 4:2 result the highest net return (Rs. 27,620/ ha) and cost benefit ratio (3.3:1) than other of the single cropping scheme

Between the cropping pattern the maximum seed yield of wheat was with cropping with soybean on the other side sorghum/ soybean inter cropping scheme was to the level achieved and lowest yield recorded was with sorghum. According to Ghosh **[14]** he concluded that the total system productivity (TSP) was recorded maximum in sorghum +wheat cropping pattern and lowest in wheat soybean system. Thakur **[15]** revealed the highest net outcome was achieved from maize +horse gram and wheat sequentially. Kamanga **[16]** refer as legume + maize intercropping pattern was far more producing and remunerative in comparison to single maize crop. Highest financial benefits were received by bush beans + sweet corn comparison to single maize cropping. An inter cropping is quiet helpful for enhancement if total yield followed by low investment to input by changing plant density and cropping pattern

Ullah **[16]** founded in maize + soybean if the distance us 90 cm for double rows can achieve a maximum yield of 6.71 tons per hectare increasing the maximum land equivalent ratio of (1.62) was revealed at 90 cm spacing of double rows comparison the normal mono cropping of maize yield is Rs. (52653.50 tons per hectare) and if inter cropping is done with maize + soybean the yield can be achieved up to net income (Rs. 56043.50/ ha). **Dhima *et al*., (2007) [17]** have recorded the most profitable with oat + Vicia *sativa* (65:35) and wheat + *Vicia sativa* + (55:45) concluding monetary advantage index (MAI) values and higher intercropping advantages (IA) was quiet higher.

An economic evaluation of intercropping maize, kenaf and African yambean was carried out based on agronomic data. Sole Kenaf and Kenaf/African yam bean intercrop yielded promising Marginal Rate of Return (MRR) of 1096 and 640.5% respectively for year 2003 while sole Kenaf, Kenaf/African yam bean and maize/Kenaf intercrops gave MRR of 1104.4, 620 and 71.9%, respectively in year 2004. In addition, the minimum rate of return analysis suggests that even under worst situations, Kenaf/African yam bean intercrop has the potential of generating acceptable returns on investment with a MRR of 700%. This performance is also not affected by possible fluctuation in input and output prices as shown by the sensitivity analysis in which the MRR was higher than the 50% minimum criterion under all considerations. Hence farmers stand to gain better when they intercrop Kenaf with African yam bean **[18]**.

The economic analysis of wheat yield data indicated that an increase in net return of Rs. 8055 ha^{-1} in soybean-wheat rotation was obtained in control (no-N fertilizer). The results further indicated that soybean based rotation reduced the fertilizer N requirement of subsequent wheat by 50%. These results suggest that inclusion of soybean in cropping system maintains soil fertility and enhances wheat. Legumes contribute to the soil organic N pool and to subsequent crops production **[19]**.

The intercropping of pigeonpea + maize increases the yield to 8970 kg ha-1 at ratio of 2:4 row spacing as a result population of 50:100 was attained. The increase in the population of the pigeonpea + maize was 50:100 at 2:2 and 1:3 row ratios. Results indicated that there was reduction in the productivity of the sole crop but loss is recompensed by the total yield and income of both the intercropped crops. As compare to the profit values for single crop of sesame, intercropping of the mung bean+ sesame is considered to be more profitable and productive **[20]**.

The highest pigeonpea equivalent yield of 11.21 q ha^{-1} (6.72 q ha^{-1} from pigeon pea and 13.27 q/ha from maize) was obtained from T6, which was statistically at par with T5 where a pigeon pea equivalent yield of 10.76 q ha^{-1} (6.50 q ha^{-1} from pigeon pea and 12.58 q ha^{-1} from maize) was recorded. T5 and T6 recorded the highest values for net return (Rs. 10 379 and 10 301/ha, respectively) and benefit: cost ratio (1.68 and 1.67, respectively).

EVALUATION OF INTERCROPPING SYSTEMS

For determining the benefits and drawbacks of different intercropping system over single cropped system LER (Land Equivalent Ratio) is used **[21]**. There are different competition functions like AYL (Actual yield loss), RCC (Relative Crowding Coefficient), LER (Land Equivalent Ratio), CR (Competitive Ratio), intercropping advantage and monetary advantage index for evaluation of system efficiency and financial benefits of intercropping systems. For maize + bean intercropping, these indices have not been used to find out the economic advantages, resource use efficiency and competition among species of intercropping system.

The biological yield, efficient land use and productivity can be increased by intercropping of crop with cassava. Intercropping of cowpea+cassava give higher yield, AHER, ATER and LER as compared to respective sole cropping **[22]**. High values of LER was also determined by others for intercropping of maize crop as compare to sole maize crop.

A simulation model was developed for evaluation of maize + groundnuts **(Figure 4)**, maize + bean intercropping systems to determine the most yielding planting methods. Evaluation of intercropping systems was based on weather data; they compared maize plant density, optimum planting time, optimum water consumption, bean plant density to attain the highest MV (Monetary value), LER, EV (Energy value). By comparing all possible combination of factors, they found LER values more than unity, expressing that maize + bean intercropping enhances overall system productivity. The study of showed that production of intercropping system is higher if there is availability of early irrigation to the crop.

Although beans yields were a bit decreased in the intercropped system yet bean plant population did not have effect on maize yield, indicating that maize yield remain unaffected by bean intercropping to significant extent. Higher beans population gave maximum financial benefit while high densities of maize enhanced maize productivity **[23]**. Conversely, intercropping did not have substantial influence on cassava tuber yield while it decreased yield of seed maize and melon than sole cropping **[22]**. **Saban, et *al.* (2008) [24]** compared planting combinations including common bean (*Phaseous vulgarism* L.), maize (*Zea mays* L.) or cowpea to determine system efficiency. They studied diverse plant density with different planting configurations comprising of sole planting of common bean and cowpea

(285,750 plant ha^{-1}) and sole plantation of maize giving population of 71,000 plant ha^{-1} and 2 planting patterns with 6 different maize + legumes series including 67:50, 50:50, and 100:50, respectively. For evaluation of intercropping system various competitive functions like aggressively, AYL (Actual Yield Loss), LER (Land Equivalent Ratio) and RCC (Relative Crowding Coefficient) were used. Intercropping index and monetary advantage index was used to determine economic evaluation, In the light of results of the study it was revealed 67:50 plant densities for both maize-common bean and Cowpea-Maize intercropping systems found to be beneficial in terms of land use efficiency owing to its better yield and monetary benefits compared respective sole planting irrespective of planting patterns.

Maximum land equivalent ration (1.29) was at 120 cm spaced triple row strip + mash bean and minimum LER (1.09) was observed in maize at 60 cm spaced row + mung bean . Maximum maize seed yield (6.7 t ha^{-1}), Soybean + Maize intercropping sown in double row strips at 90 cm spacing reported LER value of 1.62 Ullah **[24]**. LER values of 1.48-1.56 by Mason **[25]**, 1.50-1.73 by Mba and Ezumah **[26]** and similarly higher LER values in cassava + maize intercropping; 1.36-1.84 by Ezumah **[27]** and 1.16 to 1.69 by Osiru and Hahn **[28]** are concomitant to this finding. Similarly, Egbe and Adeyemo **[29]** and Amanullah **[22]** testified same results related to Land Equivalent Ratio LER among different intercropping systems.

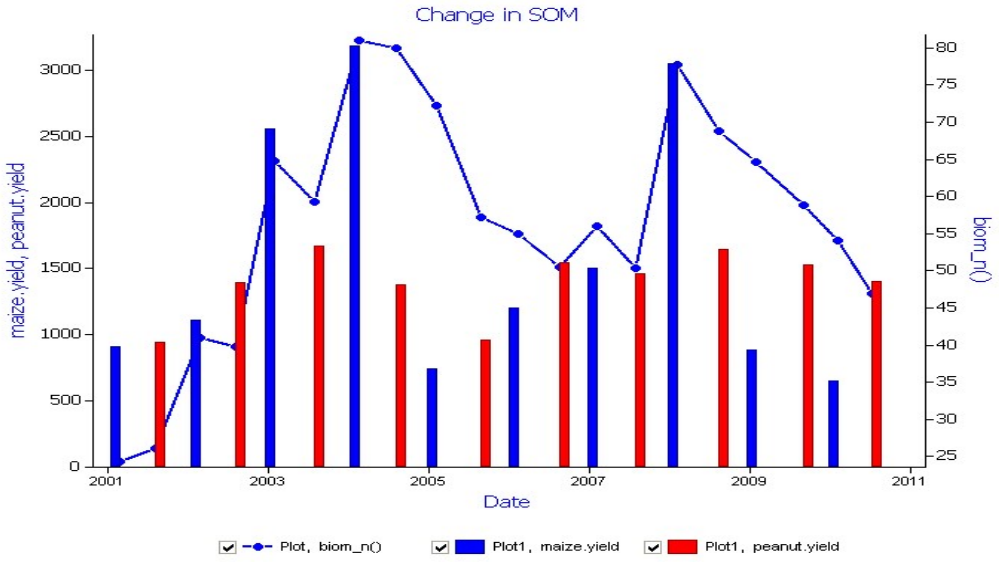

Figure 4: Graph indicating maize yield (SOM) in intercropping/crop rotation with peanut crop. Yield was considerably increased by intercropping

FUTURE OF INTERCROPPING

Long-term fertility building requires a combined methodology instead of short-range approach and targeted way out instead of conventional agriculture approaches **[30]**. Research reported that there is 50 to 80 percent increase of yield in case of cereal + cereal intercropping system, mostly the yield of the legumes crops is in the range of 1 to 2t ha-1 **[31]**.

Including soybean in rotation is necessary because it significantly increased the grain and straw yield of the following wheat in each season in both fertilized and unfertilized N treatments as compared to wheat following maize. On an average, soybean improved the grain yield of wheat by 44.9% (741.7 kg ha^{-1}) in unfertilized, and 14.5 -14.7% (496.4-419.0 kg ha^{-1}) in fertilized N treatments. The yield obtained in soybean-wheat rotation treatment in the absence of N-fertilizer was statistically equal to the yield of 60 kg N fertilizer treatment in maize-wheat rotation. Straw yield increased in similar pattern. The N uptake by wheat straw and grain was increased significantly in each year by soybean rotation and maximum increase was recorded in the absence of N fertilizer **[32]**. Once the beneficial impacts of intercropping is realized by our farmers then all resources like mechanization could be developed and can be improve the economic values of the crops efficiently probably it takes a longer time to overcome on the present sole cropping system.

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