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Practice of intercropping and its impact on legume productivity in Egypt

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ABSTRACT
In Egypt, conserving irrigation water and raising crop output are significant concerns. Egypt's climate ranges from semi-arid and arid to desert. The number of summer legumes cultivated on a per-capita basis is declining. Excessively applied nitrogen (N) mineral fertilization and irrigation water are widespread agricultural techniques that harm the quality of the soil and the surrounding environment. It should be possible to increase overall agricultural yield while working with scarce agricultural resources through intercropping. In developing countries, intercropping is the most common farming system for increasing and maintaining agricultural production. As a widely spaced crop, maize provides ample opportunity for the practice of intercropping. Legumes are well-known for their effectiveness as intercropping companions. In light of this information, an investigation into the possibility of intercropping maize with legumes, specifically groundnut and green gram, was carried out. Seeds for groundnuts and green grams were sown between rows of paired row maize. The results demonstrated that the intercropping system had no considerable impact on maize grain and straw yields. However, there was a substantial disparity in total biomass production between the experiments; maize and groundnut (2:3) recorded the highest yield, followed by groundnut (2:2) and green gram (2:3). The land equivalent ratio (LER) unequivocally demonstrated the benefits of intercropping, and the highest LER was achieved by growing maize and groundnut (2:1).

Keywords: Cropping systems, Intercropped legumes, Maize, MEY, RCBD.
Article type: Research Article.

INTRODUCTION
Small farmers throughout the world's tropical and subtropical regions employ a form of agriculture known as intercropping that combines the cultivation of legumes and cereals (Glaze-Corcoran *et al.* 2020; Hong *et al.* 2020

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Shevchenko *et al.* 2021; Rakhimova *et al.* 2021; Amraei 2022). Traditionally, the goal of this method of farming was to reduce a farm's reliance on a single crop, increase the number of different products that could be harvested, make better use of the available resources, and boost farm income from smaller holdings (Rodriguez *et al.* 2020; Uher *et al.* 2020; Hailu & Geremu 2021). The scientific research that went into the development of this idea demonstrated, however, that cereal-legume mixes are typically chosen as a method for addressing issues concerning soil erosion, a decrease in the soil organic matter level, availability of nitrogen to the companion or following crop, despite increased yield of intercropped legumes (Zhang *et al.* 2019; Jensen *et al.* 2020; Tang *et al.* 2021). Maize is a major cereal crop in many industrialized and developing countries around the globe, accounting for the majority of human food consumption (Yang & Fan *et al.* 2018; Yang & Sui *et al.* 2018; Iqbal *et al.* 2019; Li *et al.* 2020; Namatsheve *et al.* 2020). It has become the "queen of cereals" since it is a versatile crop that can be cultivated in various agro-ecological regions and has the highest output potential of any cereal crop on the planet (Nasar *et al.* 2020; Patra & Dawson 2022). In India, it is grown on over 8.69 million hectares, producing 21.81 million tonnes and average productivity of 2509 kg ha^{-1} (Baradhan & Kumar 2018; Rani *et al.* 2018; Sandesh *et al.* 2018). Maize's larger row spacing allows for the intercropping of legumes, which increases yield (Fig. 1).

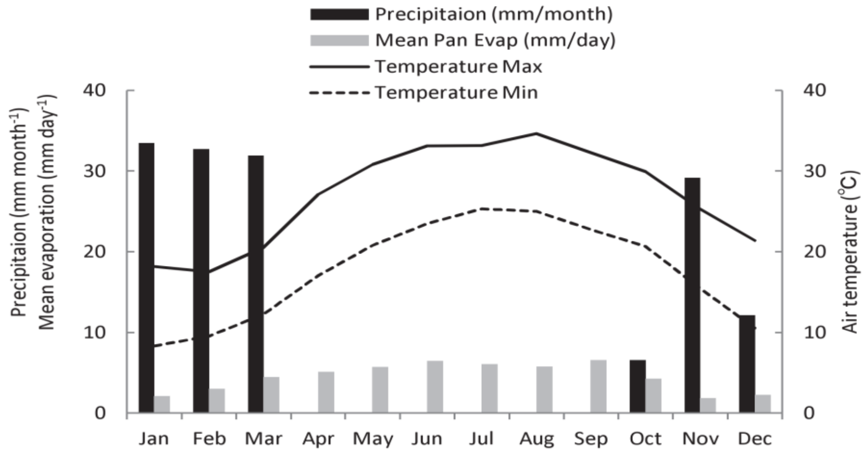

Fig. 1. Climate data of 2021 in Kafr El-Sheikh, Egypt.

Intercropping's primary goal is to boost total production per unit area and time, as well as to make more equal and rational use of land resources and farming inputs, such as labour, with the added benefit of crop failure insurance (Sandesh *et al.* 2018; Mishra 2019; Li *et al.* 2020; Morda 2020; Khanal *et al.* 2021). When grown together, the component crops are likely to complement one another, allowing for more efficient use of growing resources overall than grown individually (Nawar *et al.* 2020; Homulle *et al.* 2021). This is one of the primary reasons why intercropping results in higher outputs than growing the component crops independently. The intercropping of maize and legumes results in various benefits, including increased productivity, an elevation in the amount of nitrogen that the maize crop receives as a result of the connection, and a higher financial return (Agboola & Fayemi 1971; Ullah *et al.* 2007; Seran & Brintha 2010; Rusinamhodzi *et al.* 2012). Maize produced a greater overall yield and net return when grown with legumes. Researchers have been paying increasing attention to the system concept in agriculture in recent years (Mupangwa *et al.* 2021; Arshad 2021; Costa *et al.* 2021; Sridhar & Salakinkop 2021; Tripathi *et al.* 2021; Kutamahufa *et al.* 2022; Pierre *et al.* 2022). The crops grown using an intercropping method may or may not be sown or harvested simultaneously; however, these crops will coexist in the same field for the majority of the time that they are on the farm. Since maize is a crop that exhausts the soil, the cropping system should also include cultivating crops that replenish the soil. Therefore, planting legumes in between rows of maize is a viable strategy for addressing concerns about soil fertility and ensuring the agricultural viability of maize-based cropping systems. Since the effects of maize-based intercropping systems had not been explored in great detail under the conditions of Kafr El Sheikh Governorate, Egypt, an experiment was conducted to assess the effectiveness of maize-legume intercropping systems throughout the summer.

MATERIALS AND METHODS

The study was carried out during July 2021 and November of 2021 at the Sakha Research Station (31˚05’58” N and 30˚55’19” E), which is located inside the Agriculture Research Centre of the Arab Republic of Egypt. The region's climate is arid, with scorching hot summers and dry winters. According to Fig. 2, the location of the experiment did not receive much rain at any point during the study, except for November and the annual precipitation total for 2021 was 146 mm (Mansour & Al-Ruwaini 2022).

Fig. 2. Maize-legume intercrop.

According to Egyptian soil classification, loam soil series persist in the research region. The light soils have a lower water holding capacity than the good textured soils (loam), meaning that they require the inclusion of farm yard manure to enhance their physical state (Bhattacharyya *et al.* 2007; MacRae & Mehuys 1985). The good textured soils (loam) are excellent for cultivating any conventional crops (Ren *et al.* 2019). The test procedure was designed using a Randomized Complete Block Design (RCBD), consisting of six experiments (Table 1).

Table 1. RCBD comprising of six experiments.

Experiments	Combination	Ratio
E1		2:1
E2	Maize + Groundnut	2:2
E3		2:3
E4		2:1
E5	Maize + Green gram	2:2
E6		2:3

With three replications, experimentation was conducted using RCBD and a net plot size of 3.6 m × 7 m. The trials took place in the same experimental units for both years. The maize crop was sown at a length of 60 cm between rows, whereas legume crops were planted at a distance of 30 cm between rows. At the time of seeding, a full dose of phosphorus (115 kg ha^{-1} for maize and 55 kg ha^{-1} for legume crops, respectively) and potassium (115 kg ha^{-1} for maize exclusively) were administered. Half of the nitrogen was sprayed when the seeds were planted, and the other half was applied 30-35 days later. The first irrigation was provided during crop emergence, the second during flowering, and the third during grain growth. Weeds were controlled by hand-weeding. Both crops were harvested when 90% of the cob and pods achieved maturity. Competitive functions were computed in order to evaluate the effectiveness and competitiveness of the maize-legume intercropping system. The conversion of crop yields into a single form that may be used to compare crops grown using different crop rotation strategies, such as sequential cropping, intercropping, or mixed cropping, is known as the Maize Equivalent Yield (MEY). By considering the intercrop yield, maize market price, and associated intercrops, the yield is converted into base crop (maize) equivalent yield. The MEY is determined by transforming the intercrop(s) output into the output of the 'A' crop expressed in kg ha^{-1} at current prices. Intercropping is favourable if the equivalent yield of the base crop (maize) achieved using a variety of intercropping arrangements is higher than the base crop (maize) yield. The Land Equivalent Ratio (LER) is a concept that is used in agriculture to represent the proportional amount of land that would be needed with solitary cropping (monoculture) to achieve the exact yield as would be produced under intercropping (polyculture). In terms of the time taken by component crops in the intercrop, the Area Time Equivalent Ratio (ATER) provides a fairer comparison of intercropping yield with mono-cropping. When a crop is cultivated in conjunction with another, its Aggressivity (A) value is vital for determining its competitive capabilities. Component crops with an aggressivity rating of 0 are equally competitive. The Competitive Ratio (CR) is a metric of intercrop competition that shows how many times one component crop outperforms the other (Nedunchezhiyan 2011; Kheroar & Patra 2014; Khonde *et al.* 2018; Chhetri & Sinha 2020). The results from intercropping demonstrate that this CR term could be helpful for several purposes, including (i) comparing various crops' competitive ability, (ii) assessing competitive variations within a particular combination, (iii) discovering which crop characteristics are connected with competitive ability, and (iv) establishing what competitive balance among components is more likely to produce highest yield benefits. The stover/haulm and grain/pod yields were calculated following the routine operating technique, and they were analysed statistically employing the critical difference (CD) at the 5% probability level of significance, the Standard Error of Means (SE ± Means), and Analysis of Variance (ANOVA).

RESULTS AND DISCUSSION

Although the difference was insignificant, maize grown alone yielded higher than maize planted with legumes, i.e., green gram and groundnut, in various amounts (Figs. 3-5). Maize output was the highest, followed by maize combined with green grams in a ratio of 2:3, and then maize combined with groundnut in a ratio of 2:3.

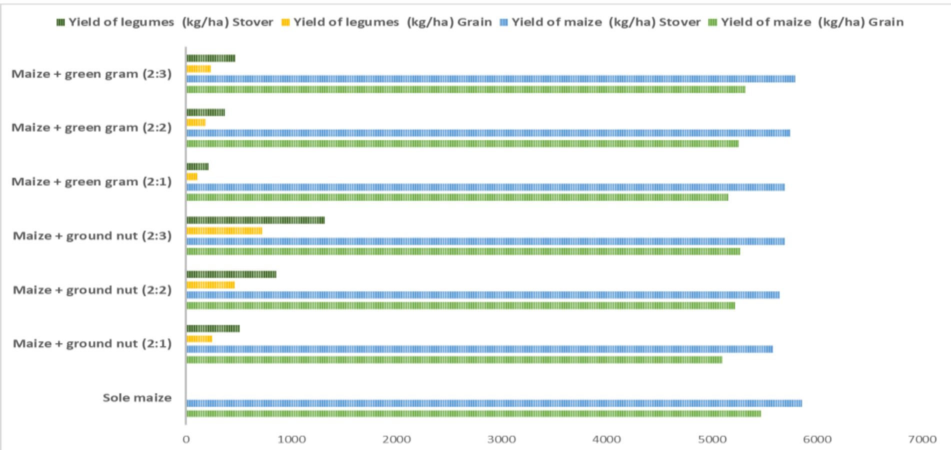

Fig. 3. Crop yield of the maize-based cropping system by intercropping with legume.

Such findings are most likely attributable to the fact that legumes shared the biologically fixed nitrogen they produced with maize. The proportion of nitrogen produced by three rows of legumes was more significant than that produced by other proportions. When compared to the other possible combinations, maize and groundnuts grown at a ratio of 2: 3 produced the most significant amount of biomass overall. Compared to other competition measures, the MEY of maize and groundnut (2:3) exhibited the highest value, while the pairing of maize and groundnut (2:2) was placed in second order. Due to the price of the products and higher yield output, the specified experiments resulted in a more significant increase in MEY. The LER was higher when maize was combined with groundnuts rather than with green gram, demonstrating advantages of intercropping. The maize and groundnut (2:1) combination displayed the highest LER, followed by maize and groundnut (2:3). When maize was intercropped with groundnut, the LER values were higher, owing to the higher groundnut yield than green grams. The benefits of intercropping are indicated by a combined LER value larger than unity (Fig. 6).

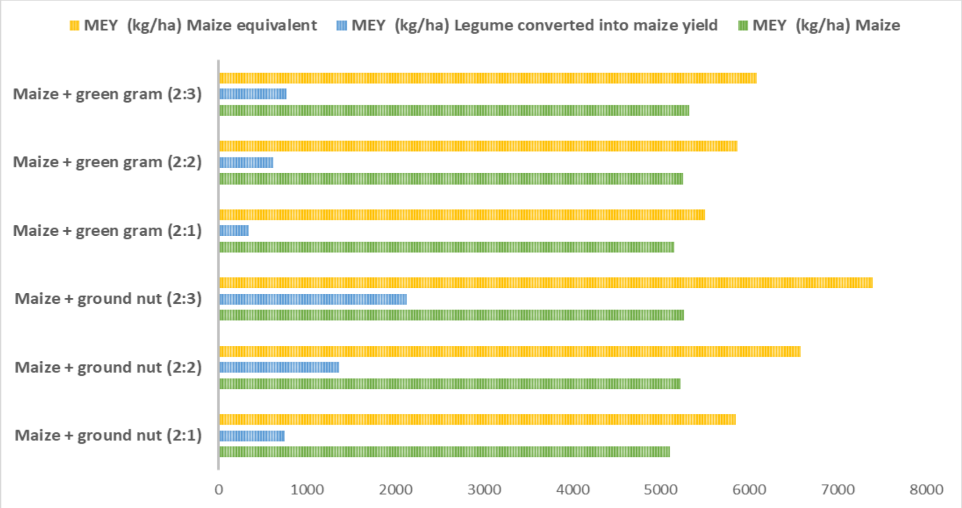

Fig. 4. MEY of maize-based cropping system by intercropping with legume.

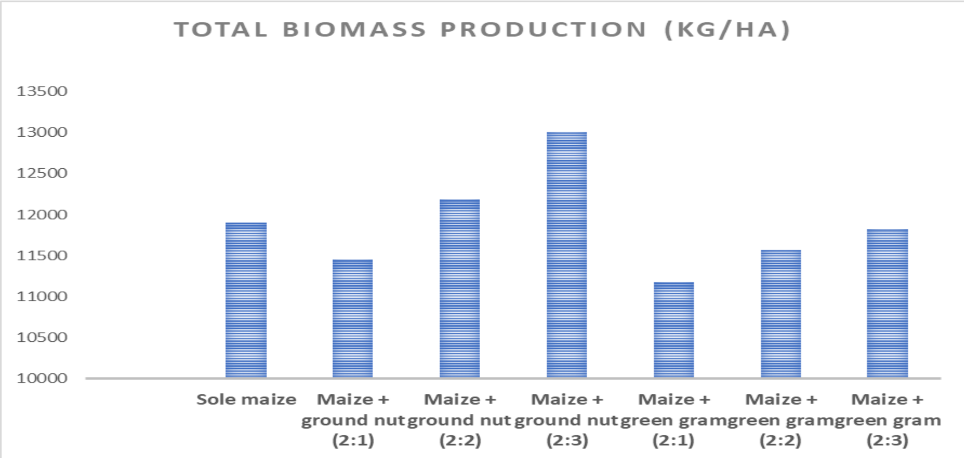

Fig. 5. Total biomass production of maize-based cropping system by intercropping with legume.

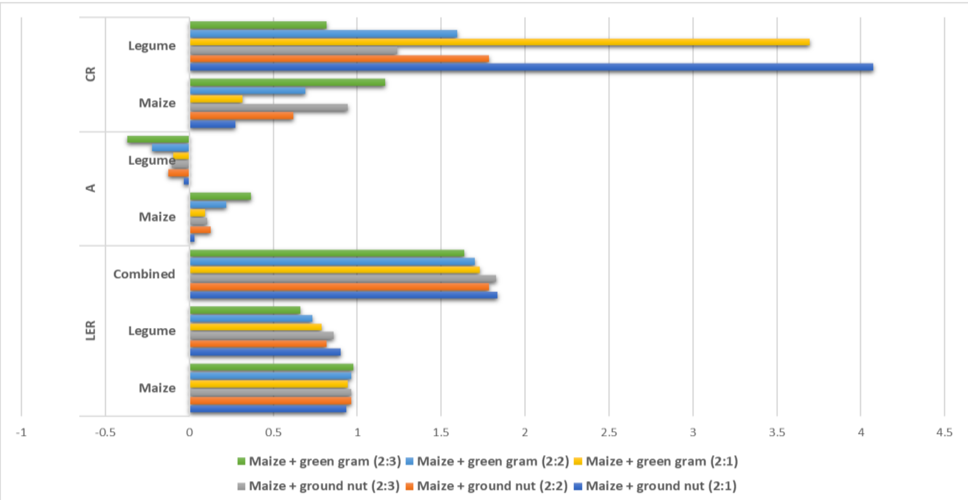

Fig. 6. LER, A and CR of the maize-based cropping system by intercropping with legume.

Except for maize and green gram (2:3), the ATER was higher than one for intercropping combinations. When ATER is higher than one, it suggests that there are yield benefits (Fig. 7). The LER, on the other hand, tends to overstate land-use efficiency while the ATER tends to underestimate it. Negative aggressiveness suggests that the species dominates, whereas positive aggressiveness implies that the species is dominating. Legumes had a higher CR than maize, indicating that they were more competitive.

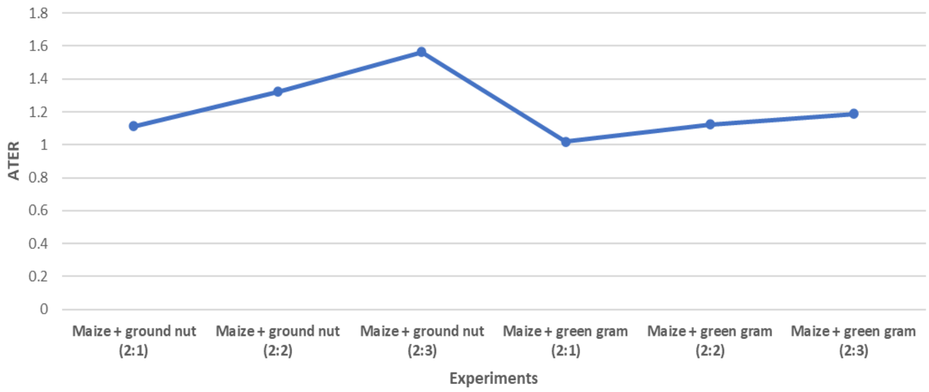

Fig. 7. ATER of the maize-based cropping system by intercropping with legume.

CONCLUSIONS

When compared to sole cropping, maize-grain legume intercropping systems were demonstrated to be more productive. For small landholder farmers, a maize-legume intercropping system would be a realistic option for increasing farm income while ensuring long-term viability. These intercropping systems can be strengthened even further by the introduction of high-yielding grain legume varieties. According to the findings of this study, intercropping legumes with maize resulted in a greater overall biomass output as well as a higher MEY yield with certain combinations. The study's calculations of competitive functions such as LER, ATER, A, and CR suggested that maize-legume intercropping is a suitable and advantageous system. The current study results allow the conclusion that groundnut is a superior component to green gram and that either two or three rows of groundnut can be planted as an intercrop in additive series of paired row maize under the conditions of Kafr El Sheikh Governorate, Egypt. Future studies should focus on grain legumes intercropping with other key crops like sugarcane and wheat to expand small landholder farmers' planting system options.

REFERENCES

Agboola, AA, & Fayemi, AA 1971, Preliminary trials on the intercropping of maize with different tropical legumes in Western Nigeria. *The Journal of Agricultural Science*, 77: 219-225.

Amraei, B 2022, Effects of planting date and plant density on yield and some physiological characteristics of single cross 550 hybrid maize as a second crop. *Caspian Journal of Environmental Sciences*, 20: 683-691.

Arshad, M 2021, Fortnightly dynamics and relationship of growth, dry matter partition and productivity of maize based sole and intercropping systems at different elevations. *European Journal of Agronomy*, 130:126377.

Baradhan, G, & Kumar, SS 2018, Studies on the effect of integrated nutrient management in the yield of maize (*Zea mays*). *Plant Archives*, 18: 1795-1800.

Bhattacharyya, R, Chandra, S, Singh, RD, Kundu, S, Srivastva, AK & Gupta, HS 2007, Long-term farmyard manure application effects on properties of a silty clay loam soil under irrigated wheat–soybean rotation. *Soil and Tillage Research*, 94: 386-396.

Chhetri, B, & Sinha, AC 2020, Advantage of maize (Zea mays)-based intercropping system to different nutrient management practices. *Indian Journal of Agronomy*, 65: 2532.

Costa, NR, Crusciol, CA, Trivelin, PC, Pariz, CM, Costa, C, Castilhos, AM, Souza, DM, Bossolani, JW, Andreotti, M, & Meirelles, PR 2021, Recovery of 15N fertilizer in intercropped maize, grass and legume and residual effect in black oat under tropical conditions. *Agriculture, Ecosystems & Environment*, 310:107226.

Glaze-Corcoran, S, Hashemi, M, Sadeghpour, A, Jahanzad, E, Afshar, RK, Liu, X, & Herbert, SJ 2020, Understanding intercropping to improve agricultural resiliency and environmental sustainability. *Advances in Agronomy*, 162: 199-256.

Hailu, H, & Geremu, T 2021, Effect of Sorghum-legume intercropping patterns on selected soil chemical properties and yield of sorghum at midland areas of West Hararghe Zone of Oromia Regional State, Eastern Ethiopia.

Homulle, Z, George, TS & Karley, AJ 2021, Root traits with team benefits: understanding belowground interactions in intercropping systems. *Plant and Soil*, 1-26.

Hong, Y, Heerink, N & van der Werf, W 2020, Farm size and smallholders' use of intercropping in Northwest China. *Land Use Policy*, 99:105004.

Iqbal, N, Hussain, S, Ahmed, Z, Yang, F, Wang, X, Liu, W, Yong, T, Du, J, Shu, K, & Yang, W 2019, Comparative analysis of maize–soybean strip intercropping systems: A review. *Plant Production Science*, 22: 131142.

Jensen, ES, Carlsson, G & Hauggaard-Nielsen, H 2020, Intercropping of grain legumes and cereals improves the use of soil N resources and reduces the requirement for synthetic fertilizer N: A global-scale analysis. *Agronomy for Sustainable Development*, 40: 1-9.

Khanal, U, Stott, KJ, Armstrong, R, Nuttall, JG, Henry, F, Christy, BP, Mitchell, M, Riffkin, PA, Wallace, AJ, & McCaskill, M 2021, Intercropping—evaluating the advantages to broadacre systems. *Agriculture*, 11:453.

Kheroar, S & Patra, BC 2014, Productivity of maize-legume intercropping systems under rainfed situation. *African Journal of Agricultural Research*, 9: 1610-1617.

Khonde, P, Congo, RD, Tshiabukole, K, Congo, RD, Kankolongo, M, Congo, RD, Hauser, S, Congo, RD, Vumilia, K & et Expérimentation, B 2018, Evaluation of yield and competition indices for intercropped eight maize varieties, soybean and cowpea in the zone of savanna of South-West RD Congo. *Open Access Library Journal*, 5(01):1.

Kutamahufa, M, Matare, L, Soropa, G, Mashavakure, N, Svotwa, E & Mashingaidze, AB 2022, Forage legumes exhibit a differential potential to compete against maize and weeds and to restore soil fertility in a maize-forage legume intercrop. *Acta Agriculturae Scandinavica, Section B: Soil & Plant Science*, 72: 127-141.

Li, C, Hoffland, E, Kuyper, TW, Yu, Y, Zhang, C, Li, H, Zhang, F, & van der Werf, W 2020, Syndromes of production in intercropping impact yield gains. *Nature Plants*, 6: 653-660.

MacRae, RJ & Mehuys, GR 1985, The effect of green manuring on the physical properties of temperate-area soils. In: Advances in soil science, Springer, pp. 71-94.

Mansour, TG & Al-Ruwaini, MA 2022, Training needs of agricultural extension agents regarding climate change in Egypt. *International Journal of Agricultural Extension*, 10(1).

Mishra, K 2019, Evaluation of maize cowpea intercropping as fodder through front line demonstration. *Journal of Medicinal Plants*, 7: 82-85.

Morda, W 2020, Faba bean and wheat as a plant team intercropping for yield improvement in Central Bekaa. (PhD Dissertation).

Mupangwa, W, Nyagumbo, I, Liben, F, Chipindu, L, Craufurd, P & Mkuhlani, S 2021, Maize yields from rotation and intercropping systems with different legumes under conservation agriculture in contrasting agro-ecologies. *Agriculture, Ecosystems & Environment*, 306:107170.

Namatsheve, T, Cardinael, R, Corbeels, M & Chikowo, R 2020, Productivity and biological N_2-fixation in cereal-cowpea intercropping systems in sub-Saharan Africa. A review. *Agronomy for Sustainable Development*, 40: 1-12.

Nasar, J, Shao, Z, Arshad, A, Jones, FG, Liu, S, Li, C, Khan, MZ, Khan, T, Banda, JSK, & Zhou, X 2020, The effect of maize–alfalfa intercropping on the physiological characteristics, nitrogen uptake and yield of maize. *Plant Biology*, 22: 1140-1149.

Nawar, AI, Salama, HS & Khalil, HE 2020, Additive intercropping of sunflower and soybean to improve yield and land use efficiency: Effect of thinning interval and nitrogen fertilization. *Chilean Journal of Agricultural Research*, 80: 142-152.

Nedunchezhiyan, M 2011, Evaluation of sweet potato (Ipomoea batatas) based strip intercropping systems for yield, competition indices and nutrient uptake. *Indian Journal of Agronomy*, 56: 98-103.

Patra, D & Dawson, J 2022, Effect of nutrient management and intercropping with cowpea on growth and yield of maize (*Zea mays* L.).

Pierre, JF, Latournerie-Moreno, L, Garruña-Hernández, R, Jacobsen, KL, Guevara-Hernández, F, Laboski, CA, & Ruiz-Sánchez, E 2022, Maize legume intercropping systems in southern Mexico: A review of benefits and challenges. *Ciência Rural*, 52.

Rakhimova, OV, Khramoy, VK, Sikharulidze, TD & Yudina, IN 2021, Influence of nitrogen fertilizers on protein productivity of vetch-wheat grain under different water supply conditions. *Caspian Journal of Environmental Sciences*, 19: 951-954.

Rani, N, Nirala, RBP, & Acharya, S 2018, Diallel analyses and heterosis of some agronomic traits in maize (*Zea mays* L.). *Pharmacognosy Journal* SP1, 3189-3194.

Ren, L, Nest, TV, Ruysschaert, G, D'Hose, T, & Cornelis, WM 2019, Short-term effects of cover crops and tillage methods on soil physical properties and maize growth in a sandy loam soil. *Soil and Tillage Research*, 192: 76-86.

Rodriguez, C, Carlsson, G, Englund, J-E, Flöhr, A, Pelzer, E, Jeuffroy, M-H, Makowski, D & Jensen, ES 2020, Grain legume-cereal intercropping enhances the use of soil-derived and biologically fixed nitrogen in temperate agroecosystems. A meta-analysis. *European Journal of Agronomy*, 118:126077.

Rusinamhodzi, L, Corbeels, M, Nyamangara, J & Giller, KE 2012, Maize–grain legume intercropping is an attractive option for ecological intensification that reduces climatic risk for smallholder farmers in central Mozambique. *Field Crops Research*, 136:12–22.

Sandesh, GM, Karthikeyan, A, Kavithamani, D, Thangaraj, K, Ganesan, KN, Ravikesavan, R & Senthil, N 2018, Heterosis and combining ability studies for yield and its component traits in Maize (*Zea mays* L.). *Electronic Journal of Plant Breeding*, 9: 1012-1023.

Seran, TH & Brintha, I 2010, Review on maize based intercropping. *Journal of Agronomy*, 9: 135-145.

Shevchenko, VA, Soloviev, AM & Popova, NP 2021 Eligibility criteria for joint ensilage of maize and yellow lupine on poorly productive lands of the Upper Volga region. *Caspian Journal of Environmental Sciences*, 19: 745-751.

Sridhar, HS & Salakinkop, SR 2021, Competitive functions, pest dynamics and bio-economic analysis in traditional maize and legumes intercropping systems under rainfed situation of South India. *Indian Journal of Traditional Knowledge*, 20: 827-837.

Tang, X, Zhang, C, Yu, Y, Shen, J, van der Werf, W & Zhang, F 2021, Intercropping legumes and cereals increases phosphorus use efficiency; a meta-analysis. *Plant and Soil*, 460: 89-104.

Tripathi, SC, Venkatesh, K, Meena, RP, Chander, S & Singh, GP 2021, Sustainable intensification of maize and wheat cropping system through pulse intercropping. *Scientific Reports*, 11: 1-10.

Uher, D, Horvatić, I & Jareš, D 2020, Influence of intercropping sweet sorghum with soybean on yield and crude protein content of fresh fodder. Conference paper, pp. 284-288

Ullah, A, Bhatti, MA, Gurmani, ZA & Imran, M 2007, Studies on planting patterns of maize (*Zea mays* L.) facilitating legumes intercropping. *Journal of Agricultural Research*, 45: 113-118.

Yang, C, Fan, Z & Chai, Q 2018, Agronomic and economic benefits of pea/maize intercropping systems in relation to N fertilizer and maize density. *Agronomy*, 8(4): 52.

Yang, X, Sui, P, Shen, Y, Gerber, JS, Wang, D, Wang, X, Dai, H & Chen, Y 2018, Sustainability evaluation of the maize–soybean intercropping system and maize monocropping system in the north China plain based on field experiments. *Agronomy*, 8(11):268.

Zhang, C, Dong, Y, Tang, L, Zheng, Y, Makowski, D, Yu, Y, Zhang, F & van der Werf, W 2019, Intercropping cereals with faba bean reduces plant disease incidence regardless of fertilizer input; a meta-analysis. *European Journal of Plant Pathology*, 154: 931-942.

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