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IMPROVEMENT IN YIELD AND NUTRIENT UPTAKE BY CO-CROPPING OF WHEAT AND CHICKPEA

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Abstract

Soil fertility and organic matter in our soils are on decline. Legume intercropping and manuring are important measures to sustain fertility and enhance productivity of soil. Four wheat cultivars Inqlab-91, WL-886, 1076 & 41 grown in field either as mono crop or intercropped with chickpea (CM 88) were evaluated with respect to yield, nutrient (N & P) uptake, compatibility and profitability. Prior to establishment of experiment, soil was enriched by green manuring of vegetative biomass of legume cereal for the last two years to raise organic matter/nutrients contents sufficienctly for growing a crop without mineral fertilizer addition. In monoculture, wheat cultivar Inqlab-91 produced the maximum grain (3294 kg ha^{-1}) than other wheat lines (WL). In intercropping system, one hactare of land produced a maximum grain yield of WL-1076 (2456 kg) along with additional chickpea grain yield (1302 kg) while an other association produced maximum grain yield of chickpea (1795 kg) along with additional wheat yield (2144 kg by Inqlab-91). Cumulative grain value (Rs. ha^{-1}) in intercropping culture was two times higher compared to that of wheat mono cropping. Associated crops accumulated significantly higher N in their biomass with a maximum of 87 kg ha^{-1} (by Inqlab+chickpea), compared to a maximum of 58 kg ha^{-1} by wheat (Inqlab-91) as mono culture. Phosphorus uptake by associated crops was also higher compared to wheat grown alone. The results clearly suggested superiority of wheat-chickpea co-cropping over wheat monoculture in terms of enhanced nutrient utilization, crop yield and farm income.

Introduction

Although fertilizers are specifically applied to replenish nutrient supply to intensive cropping system but they equally contribute to contaminate natural base resources. Prior to fertilization based agriculture, people were once acustomed to nourish their crops through natural means by incorporating crop residues in soil. Co-cropping of restorative (legume) and exhaustive (cereal) crops paved its way again in modern agriculture as an environment friendly alternative to fertilizers.

Legumes are capable to fix atmospheric N through biological means. (Vankessel *et al*., 1985). Legumes such as cowpea and groundnut generally accumulate 80-250 kg N ha^{-1} which may be available to the associated/proceeding crops as live legume excretion and/or mineralization of their plant residues (Mohr *et al*., 1999; Przednowek, 2003; Liebman & Dyck, 1993; Donald *et al*., 1963; Norman, 1996; Weber, 1966). Nitrogen fixation by legume is enhanced when associated with cereal as the excessive nitrate in the root zone is utilized by cereal (Fujita *et al*., 1992). On the other hand legume mono cropping accumulates excessive nitrate in the root zone and ultimately decrease N fixaion (Anil *et al*., 1998; Willey, 1979). While cereals are reported to deplete most of the macro and micro nutrients resulting in lower or stagnant yield even with increased inorganic fertilizer application.

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Intercropping of legume with cereal or their green manuring improve soil fertility and grain yield of the cereals (Andrew, 1979; Hinga, 1979; Gill *et al*., 2009). Intercropping can result in greater than the expected yield because of enhanced use of resources (Hauggaard-Nielsen *et al*., 2001b). Various studies showed that legume cereal mix cropping system/green manuring increase grain yield, grain N (Karpenstain-Machan & Stuelpnagel, 2000; Li *et al*., 2001) and N utilization by legumes and cereals (Fujita *et al*., 1992; Izaurralde *et al*., 1992; Ofosu-Budu *et al*., 1995). The yield of wheat was increased by 34, 27 and 19%, grown after co-cropping of maize with cowpeas, soybean and groundnuts, respectively (Nair *et al*., 1979).

The rhizodeposition of living plant or chemical changes produced on decomposition of legume residues mobilize soil bound nutrients that may be utilized by the legume itself and/or by the cereal crops growing in association or in rotation. Qureshi (1990) found that incorporating maize crop residue increased the content of available K, Ca, Mg, P, organic matter and total N in the soil. Some recent studies (Fujita *et al*., 1992; Midmore, 1993; Ikerra *et al*., 1999) showed an increase in soil fertility with the adoption of mix cropping system.

Crop diversification/green manuring is believed to be better practice for manipulating natural resourses in an effective manner and decreasing the dependence on chemical inputs thus paving the way for sustaining agricultural productivity. The apparent increase in resource use efficiency of intercrops suggests that these systems could be useful for adoption into low input or organic farming systems where options for chemical crop inputs are limited or nonexistent. Despite the potential benefits of intercropping, farmers are reluctant to use this practice just for the sake of fertility purpose rather to get some economic gains. Grain legumes (pulses) such as chickpea (*Cicer arietinum* L.) contain quality protein and are suited both for animal feed as well as for human diet (Gupta, 1988). The objectives of the foregoing studies were: i) to evaluate the compatibility of wheat cultivars growing in association with chickpea, ii) to determine the economic benefit of wheat grown either as mono crop or intercropped with chickpea, and iii) to compare N & P utilization by intercropped system and sole wheat.

Materials and Methods

Sample collection and physico chemical analysis of soil: A representative soil sample (0-30 cm depth) was collected from the experimental field. The sample was air-dried and ground to pass through a 2-mm sieve and was analyzed for pH and EC (Rhoades, 1982), $CaCO_3$ (Puri, 1931), texture (Bouyoucos, 1927), organic matter content (Walkley & Black, 1934), N (Keeney & Nelson, 1982) and Olsen P (Jackson, 1962). The soil was normal (EC=0.85 dS m^{-1}), alkaline (pH=7.9), calcareous ($CaCO_3$ equivalent = 2.3%), loam in texture, and contained organic matter content (1.5%), total mineral-N (8.73 mg kg^{-1} soil), Olsen P (14.65 mg kg^{-1}) and AB-DTPA Zn (1.30 mg kg^{-1}).

Filed experiment: Four wheat cultivars i.e., Inqlab-91, WL-886, WL-1076 and WL-41 were grown as mono crop and co-cropped with chickpea cultivar CM 88. The experiment was carried out at experimental farm of Nuclear Institute for Agriculture and Biology (NIAB), Faisalabad. The soil was initially enriched by incorporating the biomass of knee high sesbania + maize and mungbean + maize during the last two years. Chemical fertilizers were not applied throughout the experiment and the crops were allowed to get nutrition from the green manured soil. Mono crop wheat was sown conventionally with tractor mounted drill while in co-cropped culture, furrows (width = 75 cm; height = 25 cm) were prepared with the tractor. Chickpea was sown on ridges and wheat in furrows manually by a single row drill. Plant population per row of co-cropped wheat was kept same as that of mono culture wheat.

Weeding was done twice to remove unwanted weeds. Two meter long rows each of chickpea and wheat from different four places were harvested at crop maturity. Grain and straw yield was recorded and the data were converted into yield per hectare.

Plant analysis: Plant samples were dried in oven at 65°C for 3 days. Plant analysis was performed to determine total uptake of P (Jackson, 1962) and N (Keeney & Nelson, 1982) by the crops.

Statistical analysis: Data were analyzed using MSTAT-C software employing DMR test at 5% probability.

Results and Discussion

The data of grain and straw yield of four wheat cultivars (Inqlab-91, WL-886, WL-1076 & WL-41) grown either as mono crop or intercropped with chickpea are given in Table 1. In mono cropping culture, wheat cultivar Inqlab-91 produced significantly higher grain (3335 kg ha^{-1}) and straw yield (6255 kg ha^{-1}) among all the tested wheat genotypes. In intercropping system, grain yield of wheat was decreased compared to their respective sole stand. Minimum decrease in the yield was recorded in WL1076 that produced 2456 kg ha^{-1} in co-cropping compared to 2565 kg ha^{-1} in sole stand. When wheat cultivars were intercropped with chickpea, the yield of wheat and chickpea varied in each combination. In WL1076-chickpea association, grain yeald of wheat was higher (2456 kg ha^{-1}) as compared to the yield of wheat in other associations (range: 1595-2144 kg ha^{-1}). While chickpea produced the highest grain yield (1795 kg ha^{-1}) in Inqlab91-chickpea association as compared to its yield in other associations (range: 1302-1509 kg ha^{-1}). The trend of straw yield also remained similar to that of grain yield of the crops. Although wheat generally gave highest yield when grown alone (compared to the co-cropped wheat) as all the area was occupied by wheat in pure crop stand while the wheat yield in co-cropped culture was obviously low as the same piece of land was partially occupied by the component crops i.e., wheat and chickpea. Therefore in co-cropping system, the cummulative/total yield of both the component crops (wheat & chickpea) is required to be considered. Andrews (1979) found the higher commulative grain yield of the mixed cropping system as compared to sole crop culture. Bhim *et al*. (2005) also reported that pea-wheat mix cropping system increased total dry matter yield, total grain yield and their N accumulation compared to sole stand crop.

The data showed that intercropped culture accumulated significantly higher N per hactare compared to sole wheat. The maximum N was accumulated by Inqlab-91 + chickpea (CP: 55.75 + Wheat: 31.75 = 87.50 kg ha^{-1}) while as a sole crop, Inqlab-91 accumulated a maximum of 58.03 kg N ha^{-1} (Fig. 1). Cummulaive grain uptake of P ha^{-1} was also increased in wheat chickpea association when compared with wheat cultivars grown alone (Fig. 2). The maximum phosphorus was accumulated by WL1076 + chickpea (12.5 kg ha^{-1}) compared to only 7.95 kg ha^{-1} by the same wheat cultivar as mono crop. It has been reported an increase in grain yield, N uptake by plant (Eaglesham *et al*., 1981; Subedi, 1997; Karpenstain-Machan & Stuelpnagel, 2000; Li *et al*., 2001) and biological N fixation by legumes (Danso *et al*., 1987; Izaurralde *et al*., 1992; Ofosu-Budu *et al*., 1995) in cereal-legume intercropping system. Many studies revealed that nitrogenous compounds released mainly from the legume roots or on decomposition of the dead roots and nodule tissues could increase N supply to the associated cereals (Ta & Faris, 1987; Ta *et al*., 1989; Dubach & Russelle, 1994; Gill *et al*., 2006). Zhang *et al*., (2001) also reported an increase in N and P uptake by co-cropped wheat – soyabean compared to wheat alone.

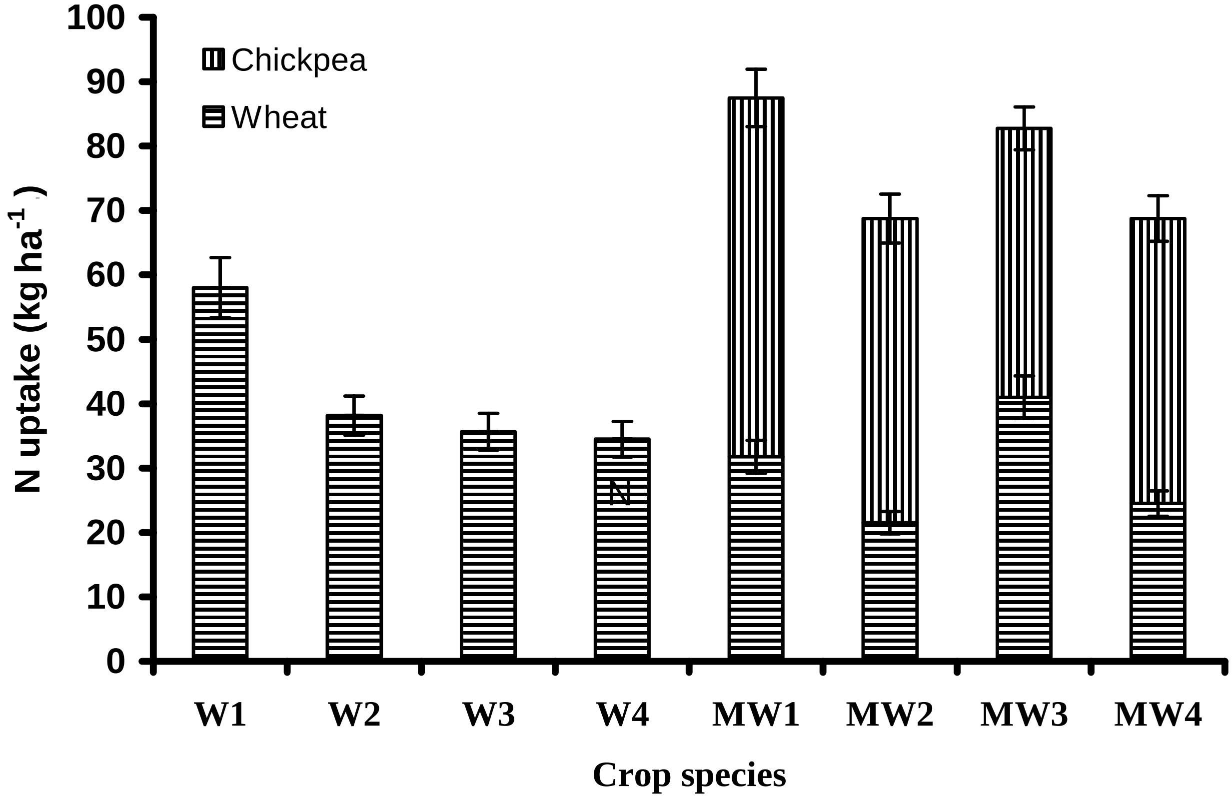

Fig. 1. Nitrogen uptake by sole wheat and wheat-chickpea association.

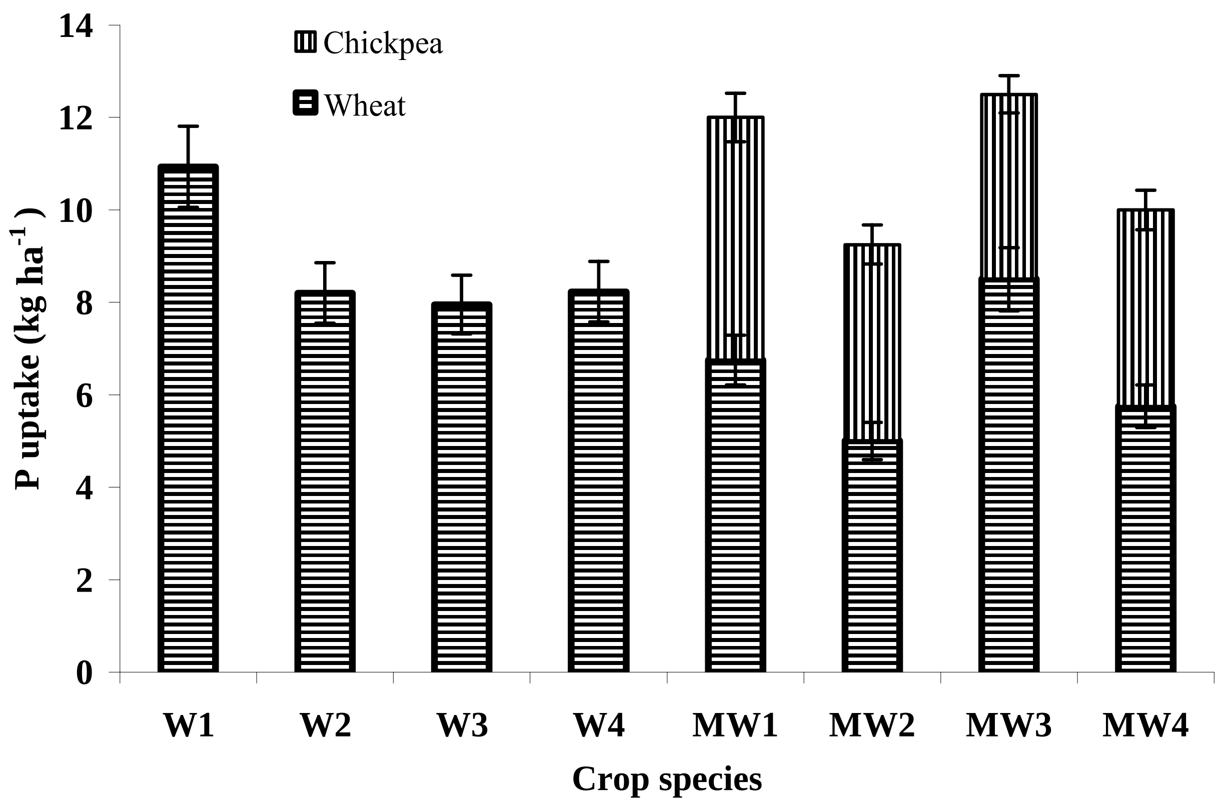

Fig. 2. Phosphorus uptake by sole wheat and wheat-chickpea association.
W_1, W_2, W_3, W_4, MW1 are Inqlab-91, WL886, WL1076, WL41, W1-chickpea mix respectively

Table 1. Dry matter yield of wheat and chickpea intercropped in a green manured field.

Species	Cropping system	Dry matter yield (kg ha^{-1})				HI	
		Grain		Straw			
		Wheat	Chickpea	Wheat	Chickpea	Wheat	Chickpea
Inqlab91	Mono	3335a	NA	5256a	NA	0.39	NA
WL886	Mono	2729b	NA	4977a	NA	0.35	NA
WL1076	Mono	2565b	NA	4611ab	NA	0.35	NA
WL41	Mono	2499b	NA	4712ab	NA	0.34	NA
Inqlab91	Mix	2144bc	1795cd	3107de	1870f	0.42	0.47
WL886	Mix	1595cd	1509d	2290ef	1644f	0.37	0.48
WL1076	Mix	2456b	1302d	4069bc	1866f	0.40	0.42
WL41	Mix	1784cd	1419d	3346cd	2205f	0.33	0.41

Figures in a column sharing the same letter(s) do not differ significantly at $p<0.05$
N.A. = Not Applicable

Table 2. Economic analysis of wheat - chickpea intercropping under green manure soil.

Species	Intercropped species	Grain value (Rs. ha^{-1})		Total grain value (Rs. ha^{-1})	Net grain value
		Wheat (A)	Chickpea (B)	C= (A+B)	Rs. ha^{-1}
Grain value of wheat grwon in mono-cropping system					
Inqlab-91	Sole crop	80,032	NA	80,032	80,032
WL886	Sole crop	65,667	NA	65,667	65,667
WL1076	Sole crop	61,555	NA	61,555	61,555
WL41	Sole crop	59,410	NA	59,410	59,410
Cumulative grain value of chickpea + wheat grown in co-cropping system					C-6000*
Inqlab-91	Chickpea	51,990	107,683	159,673	153,673
WL886	Chickpea	38,269	90,019	128,288	122,288
WL1076	Chickpea	59,664	77,995	137,859	131,859
WL41	Chickpea	43,291	86,195	129,486	123,486

*Additional cost incurred on harvesting wheat and chickpea, separately
NA = Not applicable

The co-cropped culture of wheat and chickpea was found superior to mono culture of wheat in terms of productivity and farm profitability (Table 2). All the tested wheat cultivars grown in association with chickpea produced almost two times more grain value per hactare compared to the same wheat cultivars grown alone. Although, the yield/grain value of wheat cultivars reduced in co-cropped because of land was partially occupied by the associated chickpea, however, the commulative grain value of both the component crops was increased two fold over the value of wheat grown as pure crop stand (Table 2). Andrews (1979) and Bhim *et al.*, (2005) reported an increase in total/cumulative yield of the crops grown in association as compared to the mono-crop culture.

Crop diversification has been found superior to mono-cropping system in higher farm productivity and better use of natural resources. However wise crop management is thus required to get the maximum benefit of the crop association. Legumes growing in association or in rotation with cereal crop were found to improve soil fertility in the long-term (Ta & Faris, 1987; Fujita *et al.*, 1992; Midmore, 1993; Ikerra *et al.*, 1999). Studies of various scientists (Singh *et al.*, 1992; Das, 1998) showed not only higher yield and cost to benefit ratios of chickpea-cereals co-cropping but also an increase in soil fertility (Nawaz *et al.*, 2002; Andrew, 1979; Hinga, 1979) compared to cereal as pure crop stand.

References

Andrews, R.W. 1979. Intercropping, its importance and research needs. *Field Crops Res.*, 32: 1-10.

Anil, L., R. Park, H.P. and F.A. Miller. 1998. Temperate intercropping of cereals for forage: a review of the potential for growth and utilization with particular reference to the UK. *Grass Forage Sci.*, 53: 301-317.

Bhim, B., H. Ghaley, H. Hauggaard-Nielsen, Hogh-Jensen and E.S. Jensen. 2005. Intercropping of wheat and pea as influenced by nitrogen fertilization. *Nutrient Cycling in Agro-ecosystems*, 73: 201-212.

Bouyoucos, G.L. 1927. The hydrometer as a new method for mechanical analysis of soils. *Soil Sci.*, 23: 343-353.

Danso, S.K.A., F.H.G. Zapata and M. Fried. 1987. Nitrogen fixation in fababeans as affected by plant population density in sole and intercropped systems with barley. *Soil Biol. Biochem.*, 19: 411-415.

Das, S.B. 1998. Impact of intercropping on *Helecoverpa armigera* (Hub): Incidence and crop yield of chickpea in Wert Nimar Valley of Madhya Pradesh. *Insect-Environment*, 4: 84-85.

Donald, L., H.L. Stangel and J.T. Pesek. 1963. Advances in knowledge of nitrogen fertilization in the U.S.A. since 1950. In: *Fertilizer Technology and Usage*. (Eds.): M.H. McVickar *et al*. pp. 75-129. *Soil Science Society of America,* Madison, Wisconsin.

Dubach, M.D. and M.P. Russelle. 1994. Forage legume roots nodules and their role in nitrogen transfer. *Agron. J.*, 86: 259-266.

Eaglesham, A.R.J., A. Ayanaba, R.V. Ranga and D.L. Eskew. 1981. Improving the nitrogen nutrition of maize by intercropping with cowpea. *Soil Biol. Biochem.*, 13: 169-171.

Fujita, K., K.G. Ofosu-Budu and S. Ogata 1992 Biological nitrogen fixation in mixed legume-cereal cropping systems. *Plant and Soil*, 141: 155-175.

Gill, S., M. Abid and F. Azam. 2006. Root-induced changes in potential nitrification and nitrate reductase activity of the rhizospheric soil of wheat (*Triticum aestivum* L.) and chickpea (*Cicer arietinum* L.). *Pak. J. Bot.*, 38: 991-997.

Gill, S., M. Abid and F. Azam. 2009. Mixed cropping effects on growth of wheat (*Triticum aestivum* L.). *Pak. J. Bot.*, 41: 1029-1036.

Gupta, Y.P. 1988. Nutritive value of pulses. In: *Pulse crops*. (Eds.): B. Baldev, S. Ramanujam and H.K Jain. Oxford and IBH Publishing Co., Pvt. Ltd. New Delhi, pp. 561-601.

Hauggaard-Nielsen, H., P. Ambus and E.S. Jensen. 2001. Interspecific competition, N use and interference with weeds in pea–barley intercropping. *Field Crop Res.*, 70: 101-109.

Hinga, G. 1979. *Cropping systems and soil management, soil fertility and fertilizer*. Ministry of Agriculture, National Agricultural Laboratories, Annual Report, 1979. pp. 10-11. GOK, Nairobi.

Ikerra, S.T., J.A. Maghembe, P.C. Smithson and R.J. Buresh. 1999. Soil nitrogen dynamics and relationship with maize yields in gliricidia-maize intercrop in Malawi. *Plant Soil*, 211: 155-164.

Izaurralde, R.C, W.B. McGill and N.G. Juma. 1992. Nitrogen fixation efficiency, interspecies N transfer, and root growth in barley-field pea intercrop on a Black Chernozemic soil. *Biol. Fertil. Soils*, 13: 11-16.

Jackson, M.L. 1962. *Soil Chemical Analysis*. Prentice Hall Inc., Englewood Cliffs, N.J., pp. 151-153.

Karpenstein-Machan, M. and R. Stuelpnagel. 2000. Biomass yield and nitrogen fixation of legumes monocropped and intercropped with rye and rotation effects on subsequent maize crop. *Plant Soil*, 218: 215-232.

Keeney, D.R. and D.N. Nelson. 1982. Nitrogen-Inorganic Forms. In: *Methods of Soil Analysis*. (Eds.): A.L. Page *et al*. pp. 643-698. Am. Soc. Agron., Madison, Wisconsin, USA.

Li, L., J.H. Sun, F. Zhang, X.L. Li, S.C. Yang and Z. Rengel. 2001. Wheat/maize or wheat/soybean strip intercropping. I. Yield advantage and interspecific interactions on nutrients. *Field Crops Res.*, 71: 123-137.

Liebman, M. and E. Dyck. 1993. Crop-rotation and intercropping strategies for weed management. *Ecol. Appl*., 3: 92-122

Midmore, D.J. 1993. Agronomic modification of resource use and intercrop productivity. *Field Crop Res.*, 34: 357-380.

Mohr, R.M., M.H. Entz, H.H. Janzen and W.J. Bullied. 1999. Plant-available nitrogen supply as affected by method and timing of alfalfa termination. *Agron. J.*, 91: 622-630.

Nair, K.P.P., U.K. Patel, R.P. Singh and M.K. Kaushik. 1981. Evaluation of legume intercropping in conservation of fertilizer nitrogen in maize culture. *Experimental Agriculture*, 17: 312-314.

Nawaz, H., M.M. Iqbal, S.M. Shah and W. Muhammad. 2002. Effect of intercropping chickpea with wheat on yield and soil fertility under barani conditions. In: *Abstr. 9th International Cong. Soil Sci. held at Faisalabad, Pakistan*, March 18-20, 2002. p. 18.

Norman, M.J.T. 1996. *Katherine Research Station. Annual Report*. 1956-64. A Review of Published Work. Tech. paper No.28 CSIRO, Aust. Division of Land Research and Regional Survey.

Ofosu-Budu, K.G., K. Noumura and K. Fujita. 1995. Nitrogen fixation, N transfer and biomass production of soybean cv. bragg or its super-nodulating nts1007 and sorghum mixing-cropping at two rates of N fertilizer. *Soil Biol. Biochem.,* 27: 311-317.

Przednowek, D.W.A. 2003. *The effect of pulse crop rotation and controlled-release urea on the nitrogen accumulation and end-use quality of Canada Western Red Spring Wheat*. M.S. Thesis. Univ. of Manitoba, Winnipeg, MB, Canada.

Puri, A.M. 1931. A simple method of estimating total exchangeable bases in soil (Determination of carbonates). *Soil Sci*., 31: 275-279.

Qureshi, J.N. 1990. The cumulative effects on NP fertilizers, manure and crop residues on maize bean yields and some soil properties at Kabete. *KARI Proceedings of 2nd KARI Annual Scientific Conference held at Panafric Hotel, Nairobi, Kenya* on 5-7 September, 1996. pp. 160-167.

Rhoades, J.D. 1982. Soluble salts. In: *Methods of Soil Analysis*. (Eds.): A.L. Page *et al*. pp. 167-178. Am. Soc. Agron., Madison, Wisconsin, USA.

Singh, D.R. and D.S. Yadav. 1992. Production potential and economics of chickpea (*Cicer arietinum* L.) based intercropping systems under rainfed condition. *Indian J. Agron*., 37: 424-429.

Singh, R.C., M. Singh and R. Kumar. 1992. Effect of intercropping on the productivity of chickpea. *Haryana J. Agron*., 8: 71-74.

Subedi, K.D. 1997. Wheat intercropped with toria (*Brassica campestris* var. *toria*) and pea (*Pisum sativum*) in the subsistence farming system of Nepalese hills. *J. Agric. Sci*., 128: 283-289.

Ta, T.C. and M.A. Faris. 1987. Species variation in the fixation and transfer of nitrogen from legumes to associated grasses. *Plant Soil, 98*: 265-274.

Ta, T.C., M.A. Faris and F.D.H. McDowell. 1989. Evaluation of ^{15}N methods to measure nitrogen transfer from alfalfa to companion timothy. *Plant Soil*, 114: 243-247.

Vankessel, C., P.W. Singleton, and H.J. Hoben. 1985. Enhanced N-transfer from a soybean to maize by vesicular arbuscular mycorrhizal (VAM) fungi. *Plant Physiol*., 79: 562-563

Walkley, A. and I.A. Black. 1934. An examination of the Degtijareff method for determination of soil organic matter and a proposed modification of the chromic acid titration method. *Soil Sci*., 37: 29-38.

Weber, C.R. 1966. Nodulating and non-nodulating soybeans isolines. II Response to applied nitrogen and modified soil conditions. *Agron. J*., 58: 46-49.

Willey, R.W. 1979. Intercropping - its importance and research needs. *Field Crop Res*., 32: 1-10.

Zhang, F.S, L. Li and J.H. Sun. 2001. Contribution of above- and belowground interactions to intercropping. In: *Plant Nutrition – Food Security and Sustainability of Agro-ecosystems*. (Eds.): Horst *et al*. pp. 979-980. Kluwer Academic Publishers, Doirdrecht.

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