Research Application Summary

NP fertiliser rate response of maize and sorghum succeeding sole or intercropped haricot beans

Tolera Abera
Ethiopian Institute of Agricultural Research (EIAR), Ambo Plant Protection Research Center, P. O. Box 382, Ambo, West Shewa, Oromia, Ethiopia
Corresponding author: thawwii@yahoo.com

Abstract

The role precursor crops significantly reflected on the preceding crops grown following them. Considering this a trial was conducted to asses the effects of haricot bean varieties grown as sole and intercropped on N/P rate response of succeeding maize and sorghum crop. Haricot bean varieties were significantly affected mean grain yield of maize and sorghum crops. Higher mean grain yield of maize and sorghum has recorded following sole planted haricot bean. Application of recommended rate of fertiliser following precursor crops gave higher mean grain yield of both crops. Significantly higher mean grain yield of maize had obtained with recommended rate of fertiliser indicating the importance of using fertiliser following precursor crop for maize production. Maize following Tibe variety gave higher grain yield as compared following Dicta variety. Sorghum following Dicta gave higher grain yield as compared to following Tibe variety. This indicates maize was suitable for climbing bean varieties (Tibe) as compared bush (Dicta) and vise verse for sorghum. This was due to the morphological structure of maize and sorghum and the plant population of both crops. Planting of maize and sorghum following sole planted haricot bean varieties gave higher grain yield and economically profitable as compared to following intercropped beans revealing the existence of competition between crop type in intercropping system and need for additional supply fertiliser for intercropping than using recommended fertiliser rate of the main crop. Suitability of haricot bean varieties for cropping sequence varies with crop type indicating the importance of investigating different haricot bean varieties for cropping systems. Therefore production of maize and sorghum following sole planted haricot bean with 75 % of the recommended fertiliser rate or recommended nitrogen and phosphorous fertiliser rate was suitable cropping sequence, gave higher yield and economically feasible and recommended for maize and sorghum producers of the region and similar environments.

Key words: intercropping, precursor crop, maize, and sorghum

Résumé

Le rôle des cultures de précurseurs ont beaucoup reflété sur la croissance des cultures précédentes en les poursuivant. Compte tenu de cela, une étude a été menée pour évaluer les effets des variétés de «haricots beans » cultivées seul et en association sur le taux de réponse N / P de réussir les cultures de maïs et de sorgho. Les variétés de «haricots bean » ont été touchées de façon importante le rendement moyen des grains de maïs et de sorgho. Le rendement en moyenne le plus élevé des grains de maïs et de sorgho a été enregistré lorsque le haricot a été planté seul. L'application du tau recommandé d'engrais suivant les cultures précurseur ont donné un rendement moyen plus élevé de grain de ces deux cultures. Le rendement en grains, sensiblement plus élevé du maïs avait obtenu, avec taux recommandé d'engrais, indiquant l'importance de l'utilisation des cultures précurseur pour la production de maïs. Le maïs qui vient après la variété « Tibe » a donné un rendement de maïs plus élevé par rapport à la suite variété « Dicta ». Le sorgho, venant après la variété Dicta, a donné un rendement plus élevé de graine par rapport a la précédente variété Tibe. Ceci indique que le maïs a été adapté pour l'escalade des variétés de haricots (Tibe) par rapport à la plante (Dicta) et vise versa pour le sorgho. Ceci est dû à la structure morphologique du maïs et du sorgho et du peuplement végétal des deux cultures. Les semis de maïs et de sorgho, plantés, après avoir semé une seule plante des variétés de «haricots bean », ont donné un rendement plus élevé des céréales et économiquement rentable par rapport à la suite des haricots inter cultures, soulignant l'existence d'une concurrence entre les types de cultures inter cultures dans le système et la nécessité de fourniture d'engrais pour la culture inter cultures supplémentaires que l'utilisation de taux d'engrais recommandée de la culture principale. La pertinence des variétés de « haricots bean » pour la séquence de culture varie avec le type de culture indiquant l'importance d'étudier les différentes variétés de « haricots beans » pour les systèmes de culture. Par conséquent , la production de maïs et de sorgho après avoir planté une seule culture de haricot avec 75% de taux d'engrais recommandé ou de taux d'engrais d''azote et de phosphore, était une séquence de culture appropriée, et a donné un rendement plus élevé et économiquement faisable et recommandé pour producteurs de maïs et le sorgho de la région et des environnements similaires.

Mots clés: l'inter culture, culture précurseur, le maïs et le sorgho

Background

Soil fertility reduction is a key problem for maize production in Western Ethiopia. Anthropogenic factors such as inappropriate land use systems, monocropping, nutrient mining and inadequate supply of nutrients have been aggravating the situation in the target areas. Crop rotation is necessary and a desirable management option to restore, maintain, enhance soil fertility, and maximise yield. Integrated use of appropriate fertiliser rate with suitable cropping sequence is an alternative measure to alleviate soil fertility and enhance maize yield in sustainable production system. In this study, the response to NP fertiliser rate of maize and sorghum crops succeeding sole or intercropped haricot was determined.

Literature Summary

Legumes contribute to increased productivity of other crops when incorporated into cropping systems as intercrops and through crop rotation (Giller and Wilson, 1991). Due to current land shortages, the intensity of cropping through multiple cropping systems will inevitably increase (Sahota *et al.*, 1988). Crop species in intercropping differ in their ability to take up or in their efficiency in the use of nutrients.

Appropriate cropping sequence integrated with chemical fertiliser use can increase the yield of annual crops (Henao and Bannante, 1999). Rotations with legumes build up the N status of the soil. Patwary *et al.* (1989) reported that available soil N was increased by about 32 and 40 kg/ha following chickpea and lentil crop compared with wheat. Marks and Buczynski (1998) noted that a cereal/legume mixture was the best preceeding intercrop and giving an average barley yield of 2.84 t grain/ha. A wide spread use of cereal/legume rotations has been suggested as a means to sustainability meet increasing food demands (Alvey *et al.,* 2001). The amounts of N-fixed and the proportion of plant N derived from N_2-fixation vary enormously between grain legume crops, genotypes of the same crop and environments (Giller and Wilson, 1991). Nugusse (1995) reported that haricot bean is the best crop to precede maize. However, the contribution of legumes after intercropping with a cereal compared to sole planting on succeeding maize and sorghum crop yields has not been determined. Therefore, the objective of this study was to determine the effect sole planted and intercropped haricot bean varieties on N/P rate on response maize and sorghum in the area.

Study Description

The experiment was conducted from 2004 to 2006 cropping seasons for three consecutive years at Bako Agricultural Research Centre, western Ethiopia. The altitude of the area is 1650 m. a. s. l. The mean annual rainfall is 1239 mm with unimodal distribution. It has a warm humid climate with the mean minimum, mean maximum, and average air temperatures of 13.2, 28, and 21^{o}C, respectively. Sixty percent of the soil of Bako Agricultural Research Center is reddish brown in colour clay and loam in texture (Wakene, 2001).

Haricot bean varieties Dicta (bush type) and Tibe (climber bean) were grown as sole and intercropped with maize and sorghum variety (BH-540) and (Abba Melko), respectively. Control maize and sorghum were planted as continuous cropping with recommended fertiliser rates. Recommended agronomic packages were applied for the component crops. Second and third year main maize and sorghum crops were planted as sole or intercrops with haricot beans using different N/P fertiliser rates. The trial was a factorial in a Split-split design. Haricot bean variety was the main factor, cropping system a sub-factor and NP fertiliser rate [(50, 75 and 100 % of the recommended rate (110- 46 kg NP_2O_5 ha^{-1}) for maize and (64-46 kg N P_2O_5 ha^{-1}) for sorghum a sub-sub-factor]. The gross plot size used was 5.1m x 4.5 m. and net plot size of 3 m x 5.1 m. The treatment combinations and cropping system used are given in Table 1.

The collected data were analysed using MSTATC Computer Software (Freed *et al.*, 1989). Treatment effect means were separated using the least significance difference (LSD) at 5 % probability level (Steel and Torrie, 1980). For partial budget and marginal rate of return analysis, maize and sorghum grain yield was valued at an average open market price of EB 300 and 500 per 100 kg for the last 10 years. Labour cost 20 per man-day. The cost of Urea and DAP were valued at the official prices of EB 9.00 and 10.80 kg^{-1}, respectively. Grain yield was down adjusted by 10 % to reflect the situation in the actual production system (CIMMYT, 1988).

Research Application

Maize. Cropping system significantly ($P<0.05$) affected mean plant height and grain yield (Table 2). Maize following sole haricot bean produce mean plant height of 5.77 % and gave a yield advantage of 30.4 % as compared when it followed intercropped haricot beans. This indicates a competition for fertilisers since recommended fertiliser rate was applied to maize

Table 1. Effects of haricot bean variety, cropping system and NP fertiliser rate on plant height, 1000 seed weight and grain yield of maize.

Factor	Plant height (cm)	Grain yield (kg ha^{-1})
Haricot bean variety		
Dicta	214	6489
Tibe	213	6576
LSD (5%)	Ns	Ns
Cropping system		
Intercropping	208	5671
Sole planted	220	7395
Continuous maize	208	6718
LSD (5%)	6.15	613
NP rate		
50 %	206	5903
75 %	216	6444
100 %	220	7251
LSD (5%)	7.54	751
Mean	214	6533
CV (%)	6.10	19.89

Ns= non-significant difference at 5 % probability level.

only, implying the fertiliser need for both component crops. A maizemonocrop with the recommended rate of fertiliser gave a yield advantage 18.46 % compared to maize following maize-haricot bean intercrop (Table 2). This indicates the recommended rate of fertilisers applied to maize was not enough for intercropping maize-haricot bean production and both crops was produced with shortage of fertilisers. Therefore, fertiliser rate recommendation was needed for intercropping maize and haricot bean similar to sole planting of both crops.

Application of NP fertiliser rate for maize following haricot bean was significantly ($P<0.05$) affected mean plant height and grain yield of maize (Table 1). Mean plant height and grain yield significantly increased with 50% to 100 % increased use of recommended rate of fertilisers for maize (Table 1). Significantly higher mean plant height and grain yield of maize were obtained from maize applied with recommended rate of fertilisers. Maize produced with recommended rate of fertiliser gave yield advantage of 22.84 and 12.52 % as compared to maize produced with 50 and 75 % of the recommended fertiliser rate following haricot bean varieties (Table 1). Application of recommended rate of fertilisers for maize following legumes

Table 2. Effects of cropping system, haricot bean variety and N/P fertiliser rate on plant height 1000 seed weight and grain yield of Maize.

Treatment	Plant height (cm)	Grain Yield (kg ha^{-1})		Mean
		2005	2006	
1	209	5950	4254	5102
2	204	6484	3897	5191
3	216	6935	5777	6356
4	212	8691	5872	7281
5	224	8571	5841	7206
6	220	9550	6052	7801
7	196	5055	4429	4742
8	208	6278	5508	5893
9	213	7797	5686	6742
10	206	8457	4517	6487
11	229	9240	5733	7486
12	230	10148	6066	8107
13	208	7314	6123	6718
LSD (5%)	15.02	2374	1879	1484
CV (%)	6.07	18.23	20.78	19.54

Ns = non-significant difference at 5 % probability level.

was for most importance for sustainable maize production in the region. This indicates the need of full recommended fertiliser rate following precursor crops for maize production.

The combined mean plant height and grain yield of maize were significantly ($P<0.05$) affected by interaction of cropping system, haricot bean variety and NP fertiliser rates (Table 2). Maize planted following climbing bean variety (Tibe) gave higher mean grain yield 87 kg ha^{-1} or 1.34 % as compared to following bush bean (Dicta) (Table 2). This might be due to better performance of the climbing bean variety with physical support provided from maize. On other hand, bush bean was suppressed due to shading effects from maize with intercropping and high moisture in western parts the country, which inhibits better biomass production. Significantly, higher mean grain yield of maize was harvested from following sole planted varieties of haricot bean with recommended rates of fertilisers (Table 2). Mean grain yield of maize following intercropped and sole planted bush and climbing bean varieties were significantly increased with increasing fertiliser rate from 50% to 100 % use of recommended rate of fertiliser. Significantly higher 7801 kg ha^{-1} and 8107 kg ha^{-1} mean grain yield of maize were obtained from maize planted following sole planted bush and climbing

bean with recommended rate of fertilisers (Table 2). This result suggests that sole planted haricot bean varieties as precursor crop for maize production is beneficial.

Economic analysis for fertiliser rate indicated that a net benefit of 16698 EB ha^{-1}, marginal rate of return of 202.63 % and values to cost ratio of 5.80 EB per unit investment was obtained from maize produced with recommended rate of fertiliser following precursor crops (Table 3). This was followed by maize produced with 75 % of the recommended fertiliser rate which gave net benefit of 15239 EB ha^{-1}, marginal rate return 99.14 % and values to cost ratio 7.06 EB per unit of investment (Table 3). The result confirms the need to apply recommended rate of fertiliser for maize production following different rotation or precursor crops. The lowest economic profit was obtained from maize produced with 50% the recommended fertiliser rate. Maize produced following sole planted haricot bean gave a net benefit of 19965 EB ha^{-1} as compared to maize produced following intercropped haricot bean with maize. Maize produced following sole planted haricot bean gave a net benefit advantage of 4653 EB ha^{-1} or 23.31 % as compared to maize produced following intercropped haricot bean (Table 4). Economic analyses confirmed production of maize with recommended rate of fertiliser following precursor crops and production of maize following sole planted haricot bean as compared to following intercropped haricot bean were profitable for the area.

Table 3. Partial budget and marginal rate of return (MRR) analyses for the effects of fertiliser rate on the mean grain yield of maize at Bako.

Items	Fertiliser rate (kg ha^{-1})		
	46/10 kg NP ha^{-1}	69/15 kg NP ha^{-1}	110/20 kg NP ha^{-1}
Average yield (kg ha^{-1}) Maize	5903	6444	7251
Adjusted yield kg ha^{-1}) Maize	5321.7	5799.6	6525.9
Gross field benefit of Maize	15965	17399	19578
P cost (EB ha^{-1})	540.00	810.00	1080.00
N cost (EB ha^{-1})	900.00	1350.00	1800.00
Total costs that vary (EB ha^{-1})	1440	2160	2880
Net benefit	14525	15238.8	16697.7
Values to cost ratio	10.09	7.06	5.80
Marginal rate of return (MRR)		99.14 %	202.63 %

Note: Grain price = EB 3.00 kg^{-1}, Phosphorous price = EB 10.80 kg^{-1}, Urea price = EB 9.00 kg^{-1} Yield was down adjusted with 10% coefficient, d= dominated treatment, 1$ = 17.35 EB.

Sorghum. Cropping system significantly (P<0.05) affected mean grain yield of sorghum. Significantly higher mean grain yield of sorghum was harvested following sole planted haricot bean as compared to following intercropped haricot bean varieties. This indicates application of recommended rate of fertiliser for sole planted haricot bean enhance soil fertility development as compared intercropped haricot bean planted with recommended rates fertiliser for cereals. The result ascertain the additional need of fertiliser for intercropped cereal-legumes rather than planting component crops with recommended rate fertilisers for cereals. Similar results were reported by Roy and Barun (1983). Cropping system and NP fertiliser rate did not have a significant effect on mean plant height of sorghum. NP fertiliser rate also did not significantly (P>0.05) influence mean grain yield of sorghum (Table 5). Even though the result was statistical non-significant application of NP fertiliser showed an increasing trend of mean grain yield of sorghum. Application of recommended rates of NP fertiliser gave yield advantages of 6.3 and 4.29 % as compared to 50 % and 75 % of the recommended fertiliser rates.

Table 4. Partial budget and marginal rate of return (MRR) analyses for the effects of cropping system on the mean grain yield of maize at Bako.

Items	Cropping system	
	Sole cropping	Intercropping
Average yield (kg ha^{-1}) Maize	7395	5671
Adjusted yield kg ha^{-1}) Maize	6655	5104
Gross field benefit of Maize	19965.00	15312.00
Net benefit	19965.00	15312.00
Values to cost ratio		
Marginal rate of return (MRR)		

Note: Grain price = EB 3.00 kg^{-1}, Yield was down adjusted with 10% coefficient, 1$ = 17.35 EB.

The interaction of combined treatments affected mean plant height, although non-significantly (Table 6). Mean grain yield of sorghum was significantly affected by the interaction of haricot bean varieties, cropping system and application of NP fertiliser rates (Table 6). Mean grain yield of sorghum significantly increased following sole planted climbing bean varieties with the application of recommended rates of fertilisers for sorghum. Higher mean grain yield of 4978 kg ha^{-1} was obtained following sole planted climbing bean with recommended rate of fertilisers.

Table 5. Effects of haricot bean variety, cropping system and NP fertiliser rate on plant height and grain yield of sorghum.

Factor	Plant height (cm)	Grain yield (kg ha^{-1})
Haricot bean variety		
Dicta	188	4256
Tibe	189	3963
LSD (5%)	Ns	Ns
Cropping system		
Intercropping	187	3590
Sole planted	189	4630
LSD (5%)	Ns	401
NP rate		
50 %	187	4000
75 %	186	4077
100 %	191	4252
LSD (5%)	Ns	Ns
Mean	188	411
CV (%)	8.61	20.67

Ns = non-significant difference at 5 % probability level.

Table 6. Effects of cropping system, Haricot bean Variety and N/P fertiliser rate on Sorghum.

Treatment	Plant height (cm)			Grain yield (kg/ha)		
	2005	2006	Mean	2005	2006	Mean
1	191	163	177	5507	2095	3801
2	194	167	180	5252	2222	3737
3	188	180	184	5230	2434	3832
4	216	170	193	7173	2688	4930
5	199	172	186	6385	2392	4388
6	211	199	205	7141	2561	4851
7	230	164	197	4783	2222	3502
8	213	166	189	4626	2010	3318
9	220	172	196	4475	2222	3349
10	204	161	183	6220	1926	4073
11	211	165	188	7000	2116	4558
12	194	167	181	7713	2243	4978
13	208	186	197	5300	2264	3782
LSD (5%)	Ns	21.34	Ns	1423	Ns	779.6
CV (%)	7.92	7.37	7.73	14.30	19.21	16.44

Ns = non-significant difference at 5 % probability level.

Mean grain yield of sorghum was higher following sole planted bush bean but not consistent. The result suggests that sole planted haricot bean varieties were the best precursor crop for sorghum. Therefore planting of sorghum following sole planted haricot bean applied with recommended rate of fertiliser gave better mean grain yield and is recommended for sorghum producers in the area.

Economic analysis for cropping system indicated that sorghum produced following sole planted haricot bean gave a net benefit 20835 EB ha^{-1} as compared to sorghum produced following intercropped haricot bean with sorghum (Table 7). Sorghum produced following sole planted haricot bean was gave a net benefit advantage of 4680 EB ha^{-1} or 22.46 % as compared to sorghum produced following intercropped haricot bean (Table 7). Economic analyses confirmed production of sorghum following sole planted haricot bean as compared to following intercropped haricot bean were profitable for the area.

Table 7. Partial budget and marginal rate of return (MRR) analyses for the effects of cropping system on the mean grain yield of sorghum at Bako.

Items	Cropping system	
	Sole cropping	Intercropping
Average yield (kg ha^{-1}) sorghum	4630	3590
Adjusted yield kg ha^{-1}) sorghum	4167	3231
Gross field benefit of sorghum	20835.00	16155.00
Net benefit	20835.00	16155.00
Values to cost ratio		
Marginal rate of return (MRR)		

Note: Grain price = EB 5.00 kg^{-1}, Yield was down adjusted with 10% coefficient, 1$ = 17.35 EB.

In conclusion, mean grain yield of maize significantly affected by treatment combination of cropping system, haricot bean variety, and NP fertiliser rate. Mean grain yield sorghum was significantly affected by cropping system. Maize and Sorghum planted following sole planted haricot bean gave higher mean grain yield and economically profitable as compared to maize produced following intercropped haricot bean. Production of maize and sorghum with recommended fertiliser rate following precursor crop was economically profitable. Maize and sorghum production following sole planted haricot bean with recommended

fertiliser rate gave higher mean grain yield and therefore is recommended for maize and sorghum production in the region.

References

Alvey, S., Bagayoko, M., Neumann, G. and Buerket, A. 2001. Cereal/legume rotations affect chemical properties and biological activities in two West African soil. *Plant and Soil*. 101: 45 - 54.

CIMMYT. 1998. From agronomic data to farmer recommendations. An Economics Training Manual. Completely Revised Edition. CIMMYT, Mexico, D.F., Mexico. 79 pp.

Freed, M., Eisensmith, S., Goetz, S., Reicosky, D., Smail, V. and Wolberg, P. 1989. User's Guide to Mstat-C: A Software Program for the design, management, and analysis of agronomic research experiments. Michigan State University. East Lansing. U.S.A.

Giller, K.E. and Wilson, K.F. 1991. Nitrogen fixation in tropical cropping systems. CAB International. UK. 313 pp.

Henao, J. and Baanante, C.A.1999. An evaluation of strategies to use indigenous and imported sources of phosphorus to improve soil fertility and land productivity in Mali. (IFDC). International Fertilizer Development Center. Muscle Shoals, USA. 75 pp.

Lynch, J. and White, I.W. 1992. Shoot nitrogen dynamics in tropical common bean. *Crop Sciences* 32: 392 - 397.

Marks, M. and Buczynski, G. 1998. The residual effect of fodder crop rotations and organic fertilizer application on the yield of spring barley. *Acta-Academiae-Agriculturae-ac-Technicae-Olstenensis, -Agricultura* 66: 149-156.

Nigusse Tesfa-michael. 1995. Cropping system research status and future trends in the Rift Valley: II. Weed insects pests and diseases. pp. 98-105. In: Habtu Asefa (Ed.). Proceedings of the 25th Anniversary of Nazareth Agricultural Research Center, 20 - 10 September 1995. Nazareth, Ethiopia. NARC, Nazareth.

NMSA (National Meteorological Service Agency), 2005. Meteorological data of Bako area for 1961-2005. NMSA, Addis Ababa, Ethiopia.

Patwary, S.U., Haque, Q. and Badruddin, M. 1989. Role of legume on nitrogen balance and a value of soil under different sequential cropping systems. *Thailand Journal of Agricultural Science* 22: 213 - 221.

Roy, R. N. and. Barun, H. 1983. Fertilizer use under multiple cropping systems: An overview. FAO fertilizer. *Plant Nutrition. Bull*. 6: 9 – 10.

Sahota, T.S., Grewal, G.S. and Sidhu, M.S. 1988. Increasing productivity through multiple cropping systems. *Progress farming* 24 (5): 3 – 5.

Steel, R.G.D. and Torrie, J.H. 1980. Principles and procedures of statistics: a biometrical approach. 2ed. McGraw-Hill. New York, 631p.

Wakene Negassa. 2001. Assessment of important physicochemical properties of dystric udalf (dystric Nitisols) under different management system in Bako area, Western Ethiopia. A thesis presented to School of graduate studies, Alemaya University, Ethiopia.

Woomer, P.L. and Muchena, F.N. 1995. Overcoming soil constraints in crop production in tropical Africa. pp 45 - 56. *In:* Ahenkarah, Y., E Owusu-Bennoah and G.N.N. Dowuona (Eds.). Sustaining soil productivity in intensive African Agriculture. Seminar proceedings, 15 - 19 November 1993, Accra, Ghana.