Integration of Organic and Inorganic Fertilizers: Effect on Vegetable Productivity

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ABSTRACT

The Ethiopian highlands are characterized by high human and livestock population pressure, land degradation as a result of soil erosion, soil fertility decline and organic matter depletion, low agricultural productivity and persistent poverty. In most of the farming systems, there are low external inputs that crop and livestock production depend mainly on the soil nutrient stock. A field experiment was thus launched at Debre Zeit on Andosols (1999-2001) to evaluate the effects of Farm Yard Manure (FYM) and inorganic fertilizers application on the productivity of horticultural crops. Two selected rates of FYM (2 and 6 Mg ha^{-1} on dry weight bases), were combined with three rates of Nitrogen (N) and Phosphorus (P) fertilizers (0, 0), (61, 31) and (92, 46) kg ha^{-1} to make six treatments. A randomised complete block design with three replications was employed. Four crops (shallot, tomato, cabbage and potato respectively) were planted in a rotation on permanent plots. The treatments resulted in a significant effect on both biomass and economic yields of the crops, but shallot. Supplementing the recommended inorganic fertilizers by only 2 Mg ha^{-1} FYM resulted in a significant yield increase over the recommended rates. Also, it was found out that reducing the recommended fertilizers by one third did not significantly reduce yield, if supplemented by 2 Mg ha^{-1} FYM. This does not only reduce the production cost due to reduced fertilizer use but also improves the soil quality leading to sustainability.

Key words: Farmyard manure, inorganic fertilizer, marketable yield, organic fertilizers and relative yield index

INTRODUCTION

High human and animal population densities in some areas in the highlands of Ethiopia have surpassed land carrying capacities escalating environmental degradation. In the mixed farming system of the highlands, the harmonious interaction between the components is jeopardized and undermining the long-term stability of the production systems. Ethiopia has the highest livestock number in Africa. The traditional balance between people, livestock and their habitat and the socioeconomic systems is fast disappearing. Hence, achieving sustainable increases in agricultural production has been a priority problem of the country.

Studies in energy sector by World Bank (1984) and Cesen (1986) reported that 99% of the energy used in Ethiopian homes comes from bio-mass sources which include dung, crop residues, and woody bio-mass. These studies estimated that out of the 22.5 million tons of cattle manure annually produced, 38% is used as a fuel and out of the 21.2 million tons of crop residues produced annually 24% is used as a fuel. The remaining 76% of crop residue is left on the ground and/or is used by livestock. Other studies in Ethiopia showed that a total of over 3 million tons equivalent of nitrogen, potassium and phosphorus are removed by livestock through grazing and crop residue consumption (NCS 1992, FAO 1984). The amount of nitrogen, phosphorus and potassiumin the livestock manure produced annually in Ethiopia is estimated at 1.4 milliontons in terms of N, P2O5 and K2O (Hawando 1995).

Since only little marginal land is left for grazing, crop residues have been the major sources of animal feed. Parts of the nutrients consumed by the livestock are recovered through byproducts such as manure. However, the manure is not allowed to recycle back to the crop and grazing lands, due to its alternative uses as fuel. Rural and urban households claim about 90% of the total energy consumption of the country. For the smallholder farmers, access to agricultural inputs like fertilizers is limited. Consequently, the nutrient balance of the soil is negative in most of the farming systems.

In the past, most researches targeted determination of appropriate type and quantity of fertilizers for the best yields for particular soil type and specific agro-ecological location. This approach emphasized the use of external inputs and expensive technologies, and often disregarded farmers' knowledge and the resources at their disposal (Marc et al, 2000). However, Integrated Soil Fertility Management (ISFM) approach, which combines various existing soil fertility management techniques, is becoming the order of the day.

Farm Yard Manure (FYM) is among the important soil amendments to which farmers have access in mixed farming systems. In addition to its nutrient supply, FYM improves the physicochemical conditions of soils. The widespread use of FYM greatly depends, among others, on proper application methods, which increase the value, reduce costs, and enhance effectiveness. Often, FYM is used for vegetable crops, which have high productivity and fetch high cash value. Shallots, tomatoes, potatoes and cabbages are among the important in *Ada'a* areas. Usually, these crops are grown on backyards or small-irrigated plots where the management is intensified by rotating the crops. However, only little information is available on the fertility management of these crops in the area, in particular, and in the country in general. From the experiment conducted at Debre Zeit and Awasa, Fisseha (1983) found that 20 Mg ha^{-1} FYM with 40 kg N ha^{-1} and 20 kg P ha^{-}

[1] to be the most economical next to 20 Mg ha^{-1} of biogas slug for onion production. However, this is too high to be available for use by framers. Hence, a field experiment was conducted to determine the FYM and inorganic fertilizers combinations effects on crop productivity and soil quality.

MATERIALS AND METHODS

The study was conducted on Andosols at Debre Zeit (38^0 58''E, 08^0 44'' N and 1900 m asl) with 850 mm/year and 16.6^{0}C mean annual rainfall and temperature, respectively, during the 1998 - 2000 cropping seasons. Two selected rates (2 and 6 Mg ha^{-1}) on dry weight bases of FYM, which include dung, urine and litter, were used with three rates of N and P fertilizers {(0,0), (61, 31) and (92,46) kg ha^{-1}}. Fresh dairy cows manure was piled and stored for at least four months before application for decomposition (ARAKERI et al., 1962). The treatments were applied on permanent plots (6 m * 5 m) in a randomized complete block design with three replications. Keeping the treatments fixed, four crops varieties: shallot (DZSHT-68), potato (Al-624), tomato (Marglobe) and cabbage (Copenhagen), respectively, were planted in rotation under rain fed and supplemental irrigation conditions. All cultural practices other than the treatments were applied as per the recommendation for the crops. Biomass and economic yields of the crops were determined, and the products were separated in to marketable and unmarketable depending on their size, disease and pests damage, and other irregularities. AS it was difficult to compare the yields of the different test crops, Relative yield index, calculated as the ratio of the treatments mean yield to the grand mean of the crop, was used as an indicator of the long-term relative performance of the treatments with respect to soil productivity. Core sampling method was employed in order to determine the soil Bulk density. Also, double ring infiltrometer was used to determine the infiltration rates immediately after harvesting.

RESULTS AND DISCUSSION

During the first season, the effect of the treatments was not significant ($P \leq 0.05$) on the performance of the test crop shallot. This may be due to the slow availability of the nutrients from the FYM and immobilization of N. It might also be partly attributed to the poor performance of the crop due to disease. However, on the subsequent crops, tomato, potato and cabbage, the effect was significant ($P \leq 0.05$) on the biomass, marketable as well as unmarketable yields (Tables 1-4).

As shown in Table 2, two third of the recommended N and P fertilizers (31kg N and 61kg P ha^{-1}) plus 2Mg ha^{-1} FYM resulted in the least number of days to flowering, the highest biomass and highest marketable fruit yield of tomato. Early flowering and its consequent early maturity lead to reduced management cost and increased resource use efficiency. Application of the FYM not only increased crop productivity, but also improved product quality as expressed in terms of its highest marketable to unmarketable yield ratio, mainly due to reduced cracking and improved size, particularly for the reduced application of fertilizer (Fig.1). On the other hand, application of only FYM depressed the performance of the crop, even as compared to the control. The least marketable yield was obtained due to application of 6Mg ha^{-1} FYM, followed by the 2 Mg ha^{-1} FYM.

Besides its lowest marketable yield, application of both 2 and 6 Mg ha^{-1} FYM alone, delayed the flowering dates. Moreover, the lowest straw yield was obtained due to 2 Mg ha^{-1} FYM application. It can thus be concluded that, in short time, regardless of its quantity, manure alone is not sufficient for optimum yield of the crop. The cumulative effect of continuous FYM application, however, might result in better crop performance as it gradually improves soil quality.

Similar result was obtained for potato planted next to tomato. The effect of the treatments was statistically significant ($P \leq 0.05$) on both the biomass and tuber yields (Table 3). The highest biomass and tuber yields were obtained due to the recommended rates of N and P fertilizers plus 2 Mg ha^{-1} FYM, followed by two third of the recommended rate plus 2 Mg ha^{-1} FYM, and the recommended N and P fertilizer rates without FYM, respectively. However, the difference between these three treatments was not statistically significant. One may therefore go for the least cost, which in this case is the reduced N and P rate with 2 Mg ha^{-1} FYM, although detailed economic analysis is required. The difference in the number of marketable and unmarketable tubers was not statistically significant for the treatments. Application of 2 Mg ha^{-1} FYM gave the lowest biomass yield, and the second lowest tuber yield next to the control.

Like the forgoing, the effect of the treatments was significant on both marketable and unmarketable yields of cabbage planted following potato. The highest marketable (64.4 Mg ha^{-1}) and unmarketable (36.4 Mg ha^{-1}) yields, respectively, were obtained due to application of the recommended rates of N and P fertilizers plus 2 Mg ha^{-1} FYM (Table 4). Thus, supplementing the recommended rate with only 2 Mg ha^{-1} FYM, which is much less than what has been recommended for onion by Fisseha (1983) resulted in over 13 % increase in marketable cabbage yield. As compared to the control, the recommended rate of N and P alone increased the marketable yield by 58%, while complementing it with 2 Mg ha^{-1} FYM resulted in 79% increase. This confirms the significance of synergetic effects of the organic and inorganic fertilizers on crop performance. Reducing the recommended rate of N and P by one third and supplementing it with 2 Mg ha^{-1} FYM gave the third highest marketable yield, which is 51% increase over the control. Unlike the case for tomato and potato, this is significantly less than the yield obtained due to application of the recommended N and P plus 2 Mg ha^{-1} FYM. On the contrary, the lowest marketable and unmarketable yields were obtained for the control and 2 Mg ha^{-1} FYM plots, respectively.

It should be underscored that with the application of only little quantity of FYM, the amount of the inorganic fertilizers required can be substantially reduced without compromising yield. This is elucidated by the fact that both the recommended rate and two third of the recommended rate plus 2 Mg ha^{-1} FYM resulted in 50% increase in marketable yield of tomato as compared to the control (Table 2). The Relative Yield Index showed that the treatments with the recommended rates of N and P fertilizers have tend to dominate with the while the best performance is when these rates are supplemented with 2Mg ha-1 FYM (Fig.1). The highest sum of the Relative Productivity Index for the four crops (Fig.2) obtained due to the recommended N and P fertilizer supplemented by 2Mg ha-1 FYM confirms that this treatment is relatively stable with respect to soil productivity.

The rate of infiltration has generally shown a significant improvement (Fig. 3) for the treatments receiving FYM over the period of the experiment. The highest rate was observed with application of 6 Mg ha-1 FYM, against the lowest obtained with the control treatment. This indicates that the soil quality being enhanced due to the improved soil organic matter and nutrient management. As shown in Table 5, the result of bulk density measurement was erratic that no clear trend could be observed. It is, however, expected to improve under long-term application of FYM.

To sum up, supplementing the inorganic fertilizers with FYM substantially increased both quantity and quality of the products, particularly for tomato, potato and Cabbage. The decision whether to apply the full dose of recommended rate of the N and P or the reduced rate depends on various socio-economic factors such as the efficiency, profitability, affordability, and availability of the fertilizers. Under no limitation of fertilizer input, one may go for the recommended N and P fertilizers plus 2 Mg ha^{-1} FYM. As far as the agronomic productivity is concerned, particularly for these three crops, under similar circumstances, 2 Mg ha^{-1} FYM may be sufficient under both scenarios, with recommended or two third of the recommended N and P fertilizers. This is particularly attractive for small farmers owning only few cattle as they produce little manure annually.

Among the constraints of using FYM for soil fertility maintenance in central highlands of Ethiopia is its availability due to its use as a source of energy. Compared to the other part of the country, the number of cattle is also limited by the availability of feed, and hence the quantity of manure available for on-farm use is inadequate. However, it is imperative that the scantly available manure be utilized in integration with the inorganic fertilizers to increase efficiency and encourage farmers to look for alternative sources of energy, and hence use FYM for soil fertility maintenance.

CONCLUSION

Although the effects of FYM on crop productivity and soil parameters is revealed in the long-term, based on the data for three seasons, the following can be tentatively concluded:

Supplementing the recommended N and P fertilizers rates with FYM can further improve crop productivity. The recommended rates of N and P fertilizers can be reduced by one third without significantly affecting yield with supplemental application of FYM. Only 2 Mg ha^{-1} FYM is sufficient as a supplement for optimum crop performance. Alternative energy sources need to be searched and adopted in order to avail FYM for soil fertility maintenance. Hence, Agro forestry system where fuel wood and feed are among the products; Biogas technologies where house hold energy and slug are the outputs; Solar energy where no organic matter is oxidized could be some of the substitutes that should be evaluated for use in the system.

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Table 1 Effect of one season FYM and inorganic fertilizers application on the performance of shallot

Treatments	Bulb yield (Mg ha^{-1})	Straw yield (Mg ha^{-1})
Control	1.61	3.17
6Mg ha^{-1} FYM	1.98	3.24
92kgN ha^{-1} + 46kgP ha^{-1}	1.72	3.50
2Mg ha^{-1} FYM	2.01	3.21
2Mg ha^{-1} FYM + 61kg N, 31kg P ha^{-1}	2.17	3.94
92kgN ha^{-1} + 46kgP ha^{-1} + 2Mg ha^{-1} FYM	2.07	3.38
LSD (0.05)	NS	NS
CV (%)	26.23	13.36

Table 2 Effect of two-season FYM and inorganic fertilizers application on performance of tomato planted following shallot

Treatment	Days to flowering	Fruit yield (Mg ha^{-1})		A to B ratio	Straw yield (Mg ha^{-1})	% Increase marketable yield
		Marketable (A)	Unmarketable (B)			
Control	55.33^{AB}	34^{B}	29	1.17	8^{C}	-
6Mg ha^{-1} FYM	59.33^{A}	28^{B}	28	1.00	9^{BC}	12.5
92kgN ha^{-1} + 46kgP ha^{-1}	55.67^{AB}	38^{AB}	28	1.36	12^{A}	50
2Mg ha^{-1} FYM	58.33^{A}	31^{B}	26	1.19	6^{C}	-25
2Mg ha^{-1} FYM + 61kg N 31kg P ha^{-1}	49.00^{C}	47^{A}	31	1.52	12^{A}	50
92kgN ha^{-1} + 46kgP ha^{-1} + 2Mg ha^{-1} FYM	51.67^{BC}	38^{AB}	31	1.23	11^{AB}	37.5
LSD (0.05)	4.88	12	NS.		3	-
CV (%)	4.88	17.15	8.63		18.16	-

Table 3 Effect of FYM and inorganic fertilizers application on performance of potato planted subsequent to shallot and tomato (after three seasons)

Treatments	Number of tubers ha^{-1}			Yield (Mg ha^{-1})		% tuber yield increase over the control
	Unmarketable (A)	Marketable (B)	Ratio (B/A)	Tuber	Straw	
Control	7597	306191	40	23.9^{C}	8.3^{BC}	-
6Mg ha^{-1} FYM	6260	375295	60	32.5^{B}	11.8^{B}	36.4
92kgN ha^{-1} + 46kgP ha^{-1}	7548	421513	56	41.9^{A}	17.9^{A}	75.6
2Mg ha^{-1} FYM	5079	406070	80	25.5^{C}	7.0^{C}	7.0
2Mg ha^{-1} FYM + 61kg N, 31kg P ha^{-1}	5960	389960	65	45.5^{A}	17.1^{A}	90.9
92kgN ha^{-1} + 46kgP ha^{-1} + 2Mg ha^{-1} FYM	6548	461287	70	46.3^{A}	18.9^{A}	93.9
LSD (0.05)	NS	NS		5.0	4.7	
CV (%)	33.8	14.9		7.6	19.0	

Table 4 Effect of FYM and inorganic fertilizers application on performance of cabbage planted subsequent to shallot, tomato and potato (after four seasons).

Treatments	Yield (Mg ha^{-1})		Marketable yield % increase
	Marketable	Unmarketable	
Control	36.0^{C}	20.5 ^{B}	
6Mg ha^{-1} FYM	41.2^{C}	22.8 ^{B}	14.5
92kgN ha^{-1} + 46kgP ha^{-1}	56.9^{AB}	33.0^{A}	57.9
2Mg ha^{-1} FYM	38.5^{C}	20.8 ^{B}	7.0
2Mg ha^{-1} FYM + 61kg N, 31kg P ha^{-1}	54.2^{B}	32.5^{A}	50.6
92kgN ha^{-1} + 46kgP ha^{-1} + 2Mg ha^{-1} FYM	64.4^{A}	36.4^{A}	78.8
LSD (0.05)	8.6	6.9	
CV (%)	9.8	13.8	

Table 5 Effect of continues FYM and inorganic fertilizers application on soil bulk density at harvesting of potato and cabbage

Treatment	Bulk density (kg/ m^{3})			
	Potato		Cabbage	
	0-30 cm	30-60 cm	0-30 cm	30-60 cm
Control	1.35^{B}	1.09	1.28^{B}	1.36^{AB}
6Mg ha^{-1} FYM	1.35^{B}	1.14	1.35^{AB}	1.30 ^{B}
92kgN ha^{-1} + 46kgP ha^{-1}	1.45^{A}	1.07	1.32^{AB}	1.13^{C}
2Mg ha^{-1} FYM	1.33^{BC}	1.12	1.38^{AB}	1.30^{B}
2Mg ha^{-1} FYM + 61kg N, 31kg P ha^{-1}	1.26^{C}	1.05	1.34^{AB}	1.47^{A}
92kgN ha^{-1} + 46kgP ha^{-1} + 2Mg ha^{-1} FYM	1.31^{BC}	1.05	1.40^{A}	1.29^{B}
LSD (0.05)	0.08	NS	0.10	0.15
CV (%)	4.87		5.97	8.68

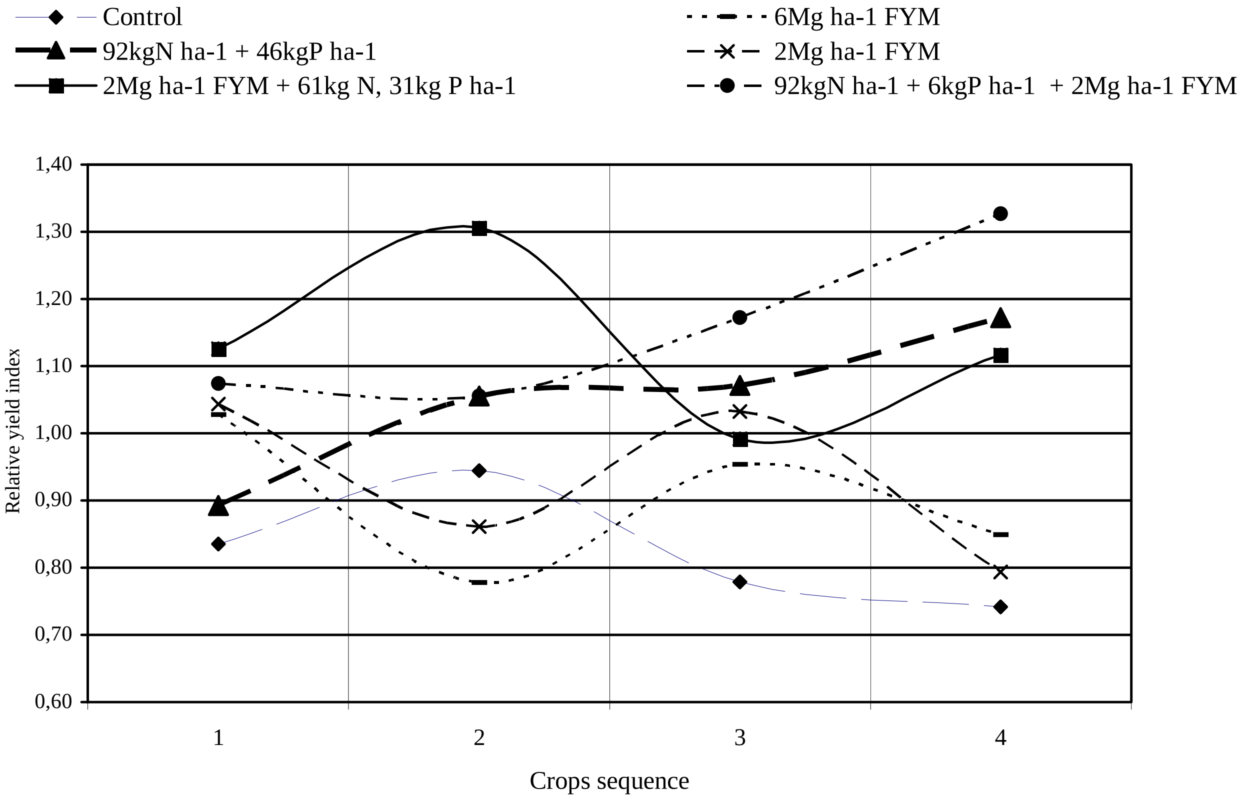

Fig. 1 Relative Yield Indices of the treatments for the first cycle

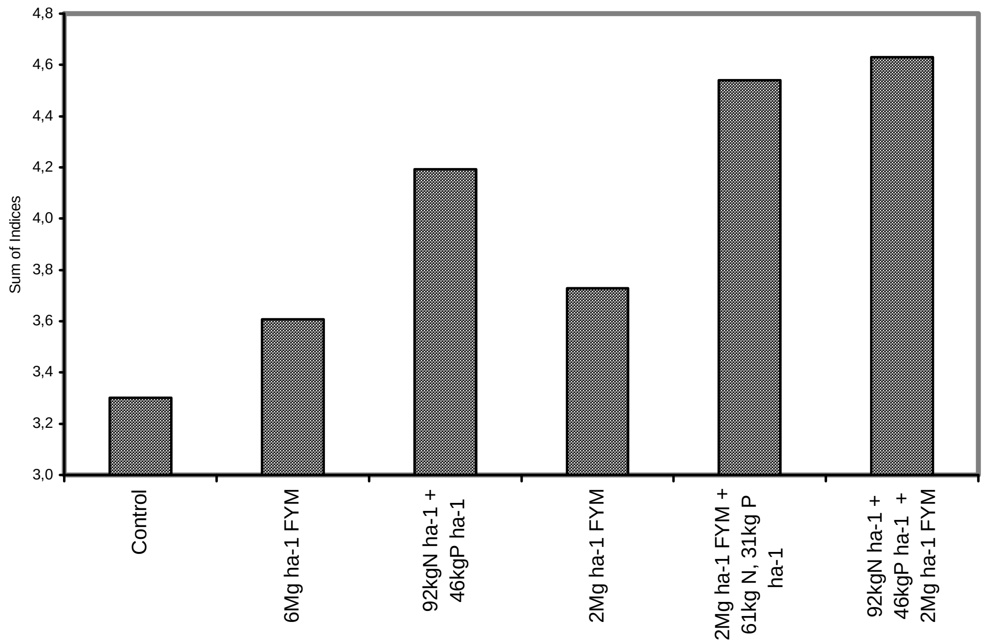

Fig. 2 Cumulative Relative Productivity Indices of the treatments during the first cycle

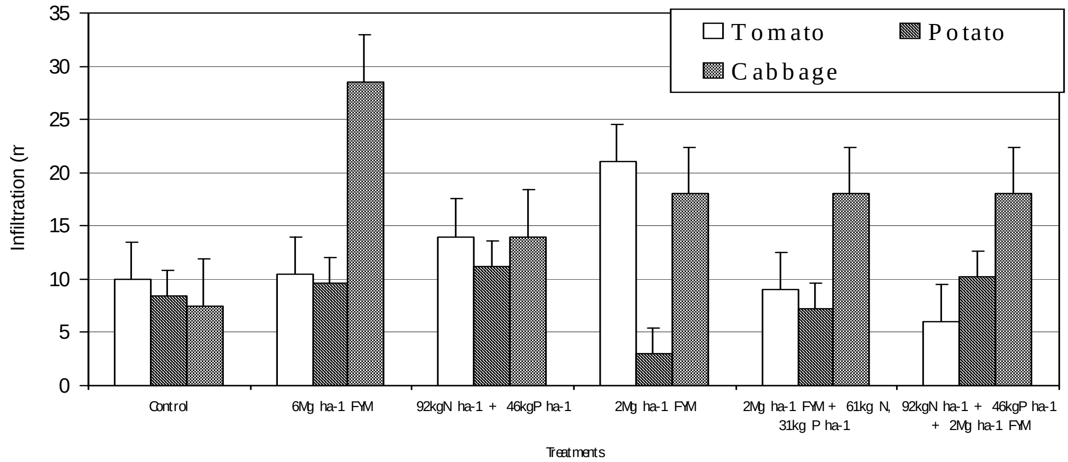

Fig. 3 An infiltration rate of the soil as affected by continues application of the treatments to the subsequent crops.