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ADVANCES IN SOIL MANAGEMENT TECHNOLOGIES TO ENHANCE ORGANIC AGRICULTURE IN NEPAL

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ABSTRACT

Agriculture is the mainstay of the national economy which accounts for about 34.1 % of the GDP and 65.5 % of the employment. Currently Nepal needs sustainable agriculture production for the maintaining soil and crop productivity for the long run. Soil organic matter has different functions in plant growth and developments. The liberation of nutrients from the organic materials occurs during the microbial decomposition dynamics of soil organic matter. Mineral fertilizers are expensive commodities and small and marginal farmers are not able to use these fertilizers in adequate amount. On the other hand, soil quality is deteriorating due to imbalance and inadequate use of mineral fertilizers and lacking of soil organic matters. To maintain soil fertility using organic and biological fertilizers in combination with the mineral fertilizers has its own importance under integrated plant nutrient system (IPNS), which aims at maintaining soil fertility for sustainable and environmentally sound agricultural production. There is no universal IPNS application to all circumstances. The suitable combination of mineral fertilizers, organic manures, crop residues, and biofertilizer varies according to the cropping systems, land use systems, ecological, social and economic condition. A number of studied were carried out in the country to identify the best combination of various plant nutrients sources to sustain soil fertility. The results of some of these studies are briefly disused in this review paper.

BACKGROUND

Agriculture is the mainstay of the Nepalese economy and population engaged in agriculture to provide livelihood for more than 65.5% of the total population. The population growth rate is currently 2.25 % while the growth rate of food grain production is only 2.16 % (SINA, 2009/010). The production gains achieved so far are attributed mainly to an expansion in cultivated land area, rather than an increase in yield per unit area. More and more marginal land has been brought under cultivation, and there is little potential for further increase in cultivated area. The emerging shortfall in domestic food production might be resolved only through increased productivity of existing cropland. On the other hands, environment pollution is also a major issue, which has emerged from adoption of modern agricultural technologies and mismanagement of agriculture practices. Accordingly, the Twenty-Year Agriculture Perspective Plan (APP/Nepal) has emphasized a boost in productivity to meet the needs of the growing population without deteriorating soil and environment.

Soil fertility management is the key towards this strategy, as crop production is often limited by deficiencies of soil nutrients. Nutrients are supplied to crops through applied fertilizers and through microbially mediated release of organic nutrients held in the soil organic matter, which contains more than 90% of the nitrogen (N) and sulfur (S) in surface soils and up to 75 percent of the phosphorus (P). Changes in soil organic carbon (SOC) from the surface to subsurface horizon follows the expected decreasing trend. The decline in SOC with depth is, however, most pronounced (64-70%) for the non-eroded phase, which reflects the accumulation and concentration of organic materials near the surface of the forest soil. Less rapid decline in SOC with depth under cultivation can be attributed to considerable mixing of the upper 0.2 to 0.3 m of soil and incorporation of crop residue (Blevins and Frye, 1993; Lal et al., 1994; Bajracharya et al., 1996).

Wolfgang Flaig (1984) has reported that the soil organic matter has different functions in plant growth. The libration of nutrients from the organic materials occurs during the formation and dynamics of soil organic matter by microbial activity. Under natural conditions, plant nutrients enter the soil through the decomposition of dead plant materials. In agriculture they are added by farmers as residues of the harvest or in the form of stable manure (FYM and compost) and other organic materials. All these materials and the roots of the harvested plants are transformed during humification, the process by which inorganic plant nutrient become available for the next crop. The amount of nutritive elements in plant materials depends on their composition, which varies from plant to plant, and with the growth conditions of each plant. The N, P and S added are mainly constituents of organic compounds. Most of the other elements are present in the form of organic complexes or as ions.

In soil many transformations organic materials occurs through microbial activities. The C skeleton of compound is changed in most cases by oxidative processes. During humification the N compounds and, to a lesser extent, as NH_3, which is formed from the amino compounds and finally oxidizes to nitrate (NO_3). Some losses of N occur in gaseous form as N_2 or N_2O.

Sulfur is bound in the original organic compounds as S^{2-}, very seldom as sulfate, and transformed in the soil to sulfate. Phosphorus occurs in the organic compounds as phosphate enters, which are hydrolyzed.

Cation such as K, Ca, Mg and the heavy metals are present in plants as complexes. They are transformed during humification into ions by the destruction of the complex compounds; very often they form other complexes with newly formed organic compounds during humification. They interact with the inorganic parts of soil colloids, mainly with silicic acids, sesquioxide, and clay minerals. The rate of formation of the complexes depends on soil properties and environment. Alkali ions are sorbed by the organic or inorganic sorption complexes of soil at different rates, e.g. K ions form stronger bonds than Na ions. Therefore larger amounts of Na are transported by water to sea, which contains a relatively high Na content. Similarly the contents of P, S, Ca and Mg are a tenth of the range and those of micronutrients less than a hundredth. Plant growth depends mainly on the mode of availability of nutrients, especially N.

Fate of nutrient application in Nepal

Mineral fertilizer application in Nepal has supplied only a fraction of total nutrient requirements for the cropping systems. Nutrient consumption in Nepal is not only one of the lowest in Asia but is also highly imbalanced in terms of N, P, and K application. Among the macronutrients, N availability remains the most limiting nutrient to growth of crops. Amendment of organic manures has been the traditional source of nutrients in farming systems of Nepal, but their rates are typically also inadequate for attaining high yield levels. The amount of manures applied to the farmer's fields vary considerably, depending on the priority of the crop species grown, distance of the fields from homestead, availability of organic matter, labor, the fertility status of the soil and availability of chemical fertilizers. The long-term experiment results show that combination of organic as well as inorganic fertilizers is necessary in order to produce higher yields as well as in maintaining soil fertility in the long run.

A long-term soil fertility experiment had been conducted till 2003 at Khumaltar Research Block representing mid-hill condition to study the effect of mineral fertilizers and/or manure in soil fertility in rice wheat system. Significantly, higher yields of rice and wheat yields were obtained through the application of balanced fertilizers (NPK). This study also includes measurements of chemical nature of organic manure, but the nutrient supply from soil organic matter remains to be evaluated in this agro-ecological zone. Study on SOC is an essential and important for the soil productivity and mitigation of greenhouse effect. Supplementary of chemical fertilizer in the certain crop fully depends on the SOC level in the particular soil (Pandey et al. 1998).

Soil organic matter research

Soil organic matter is thought to be a mixture of partially decomposed plant residues, microbial exudates, and microbial cell parts. Its exact chemical structure remains unknown. Biomass of amended organic materials (crop residues, green manures and animal manures), crop management (e.g., tillage intensity), and intrinsic soil properties (e.g. clay content) and agro-ecological zones affect its quantities. Components of organic matter degrade on time scales ranging from weeks to centuries. Organic matter is often extracted as discrete fractions in an attempt to distinguish rapidly cycling materials from more recalcitrant materials. Soil organic matter is associated with improved physical, chemical and biological processes in soil. In addition to storage of substantial N, P, and S, organic matter also provides cation exchange sites for retention of cationic nutrients such as potassium, calcium, magnesium, and increases soil water holding capacity, and improves soil physical properties such as structure. It nourishes soil microbial populations. The steady release of N from organic matter through microbial degradation provides a more even N supply to the crop than would a regime of infrequent fertilizer applications, hence better matching crop N demand. Most studies in the past have focused on the quantity of soil organic matter; however some studies have also been started on effects of quality or chemical nature of soil organic matter on soil processes (Olk and Cassman, 2002).

A long-term yield decline under continuous rice cropping in the Philippines was associated with decreased availability of organic matter-bound N, although total soil N levels did not decrease. Olk et al. (1996) associated continuous rice cropping with an accumulation of phenolic compounds in organic matter, and Olk and Cassman (2002) associated such phenol enrichment with an inhibition of N cycling during the rice-growing season. Phenol enrichment was promoted with greater fertilizer inputs, presumably due to greater biomass of incorporated crop residues. Results by Noguchi et al. (1997) from rice-wheat rotations suggested chemical stabilization of certain micronutrients by soil organic matter under anaerobic decomposition of crop residues, causing a copper deficiency in rice. These results indicate the need for more information on the chemical nature of organic matter under different agronomic treatments in different soils, in an effort to better understand short and long-term processes of nutrients and soil organic matter that may influence the enhancement of soil fertility and productivity. A review of research results and farmers' experience in warm temperate (mid-hill climate) rice-based cropping systems suggest that agricultural productivity has stagnated and/or declined during recent decades. Multiple factors may be responsible for this gap. Nutrient cycling is most likely involved due to continuous mining of soil nutrients through the use of high yielding varieties and more frequent cropping, simultaneous with inadequate and imbalanced fertilization. Human population increase is the root cause of the crop intensification, which leads to serious nutrient mining in the soil, and this issue remains as a challenge for increased crop production.

Management of soil fertility and plant nutrition has drawn considerable attention in Nepal in recent years. The majority of farmers in Nepal are subsistent, and 90 % have less than 1 hectare land. Under intensified cropping, farmers are experiencing trends of declining crop productivity. A new approach in soil fertility is to increase application rates of mineral fertilizers to match nutrient output rates from production fields. This perspective forms the basis of long-term soil fertility experiments and farmer's practices on different cropping systems in mid-hills and plain Terai regions. Yet, this approach is incomplete without simultaneously studying the flows of nutrients bound in soil organic matter. Therefore, it is most essential to study the significance of soil organic matter in Nepalese agriculture.

Effects of Organic Manures in Different Crops

Nepal is divided into three agro-ecological regions, Mountain, Hill and Terai. Terai is the most potential plain area for agriculture and are suitable for several tropical and subtropical cereals, vegetables and fruits where as hill having undulating terrain with sub-temperate climate still suitable for many fruit trees, vegetables and cereals. Cropping systems in Terai is rice based and hill it is maize based. Declining trend or stagnation of majority of the crops has been reported in recent year. The reasons for declining or stagnation of the crops in hill and Terai has been reported due to soil mining caused by crop intensification with nutrient demanding high yielding verities, acidity, nutrient loss through soil erosion, in adequate and imbalanced use of mineral fertilizers and depletion of soil organic matter.

Hill farming is still compost based. Rasali et. al. (1995) reported from a farm survey in western Nepal that farmers apply between 10-50 t ha^{-1} of farm yard manures every year. FYM/Compost increases the organic matter content for the soil which is considered as an indicator of the fertility status of the soil. It is also a substrate for many beneficial macro and micro organism which are helpful to minimize the unavailable form of nutrient for the benefit of the higher plant. Use of compost/FYM has been reduced considerable due to unavailability of fodder for animal caused by deforestation. On the other hands, farmers in Terai reducing their cattle heads due to acute shortage of fodder and very less amount of animal waste are available for compost making. Whatever animal and farm waste in available some portion of them is also used for fuel purpose in Terai and very less organic matter is in used causing depletion in soil fertility. In hill farmers do not use animal dung for fuel purpose. The animal dung, mixed with leaves and twinges collected from forest is used for bedding materials and is heaped in the near by cowshed or courtyards for composting. The efficiency of such compost is very poor. Due to expose to the sun and rain most of the nutrient is washed away causing pollution in environment on the other hands most of the leafy portion not decomposed properly also get washed away by the torrential rain without providing much benefit for higher production and to increased the soil fertility.

Use of compost/FYM as well as mineral fertilizer alone has its own limitation and constraints. So plant nutrient supplied by mineral, organic and biofertilizer to meet the nutrients demand of improved varieties of cereal, vegetables and other crops without depleting inherent fertility of the soil and without having effect on soil and environment in an integrated way is the concept of integrated plant nutrient management.

Integrated Plant Nutrient Management System (IPNS) Research in Nepal

There are many research conducted regarding integrated nutrient management. A research conducted by Soil Science Division with the support of Fertilizer Advisory Development Information Network for Asia and Pacific (FADINAP) as an example. This study was conducted in terai and hill agro-ecological zones such as Belwa VDC, Parsa district and Sarada Batase VDC Kavre district. This research project was carried out since 2001 to 2002 and research methodology and experimental results are given bellow.

The vegetable grown in wider space like plant to plant 50 cm and row to row 62.5 cm (cauliflower and cabbage), the compost and mineral fertilizer were applied in pits and were mixed well in the soil and cabbage/cauliflower were planted. Radish grown at the spacing of row to row 50 cm and plant to plant 5-10 cm compost and fertilizer were applied in band and by covering with soil radish seeds were sown to reduce the loss of nutrient.

Lentil having sown at a narrow spacing e.g. plant to plant continuous and row to row 25 cm. the compost and mineral fertilizer were spread all over the plot and are incorporated before sowing the seed of lentil.

Table: 1. Treatments Detail, Recommended Dose of Mineral Fertilizer and Crop Grown and Method of Application of Manure and Fertilizer.

S. N.	Treatment Combination	Crops
1	Compost 30 t ha^{-1}	Cauliflower, Cabbage and
2	15 t compost + 60:30:20: N: P_2O_5: K_2O kg ha^{-1}	Radish
3	120:60:40: N: P_2O_5: K_2O kg ha^{-1}	Radish
4	20:40:30 N: P_2O_5: K_2O kg ha^{-1}	Lentil
4	Farmer's practice (3.5 t compost only)	

Source: Bhattarai et al. 2002.

RESEARCH FINDINGS

Cabbage

The fresh yield of cabbage and its byproduct showed statistically significant among treatments at Belwa ranging from 13.9 to 25.36 and 7.10 to 13.18 tons ha^{-1}, respectively in different treatments (Table-2). The application of well decomposed compost at the rate of 30 t ha^{-1} alone or in combination with 15 t ha^{-1} compost with 60:30:20 N: P_2O_5: K_2O kg ha^{-1} from mineral fertilizer has increased the yield of cabbage head significantly as compare to recommended dose of fertilizer alone (120: 60: 40 N: P_2O_5: K_2O kg ha^{-1}). This may be due to release of nitrate-N in the early two to three weeks from high quality compost (Tripathi and Tuladhar, 1997).

Cauliflower

The yield of cauliflower and its product from Sarada Batase are summarized in Table-3. The production at Sarada Batase was observed similar result as in Belwa. Highest cauliflower head yield 19.35 t ha^{-1} fresh wt. was obtained with the application of 30 t ha^{-1} of well decomposed compost having high nutrient content, which is followed by 15 t ha^{-1} compost combined with 60: 30: 20 N: P_2O_5: K_2O kg ha^{-1} (18.81 t ha^{-1}) and 17.03 t ha^{-1} produced with the application of 120:60:40: N: P_2O_5: K_2O kg ha^{-1}.

Table: 2. Location- Belwa VDC, Parsa District

S. No.	Crops		Yield t ha^{-1} (Average of 4 Farmers)			
			T1	T2	T3	T4
1	Cabbage	Head	25.36	25.25	17.20	13.58
		Leaves	13.58	10.18	7.38	7.10
2	Radish	Tuber	24.01	25.16	24.72	16.79
		Leaves	15.05	15.53	15.82	10.94
Second Crop-Onion			T1	T2	T3	T4
1	After Cabbage	Bulb	18.00	13.73	15.83	11.16
		Laves	4.32	3.80	3.33	3.83
2	After Radish	Bulb	14.00	14.62	14.50	2.15
		Lave	4.38	4.13	4.13	5.50

Source: Bhattarai et al. 2002.

Note: Residual + 30 kg N ha^{-1} urea was top dressed in all the plots of cabbage and radish.

Residual effect of compost, mineral fertilizer and their combination were study in both the location but results of onion in Terai grown after cabbage and after radish were documented. Onion was grown as a bonus crop in the farm fertility level after cabbage and radish in which compost and mineral fertilizer were applied in different combination. Onion received small amount of urea (30 kg ha^{-1}) as atop dressing in all the plots receiving different treatments. Yield trend in onion was also similar to cabbage and radish. Maximum yield (18.00 t ha^{-1}) was obtained when compost was applied at the rate of 30 t ha^{-1} in cabbage followed by mineral fertilizer (15.83 t ha^{-1}) Table-2.

Radish

The yield of radish tuber and their byproduct leaves are summarized in Table-2 and 3 at Belwa and Sarada Batase, respectively. The analysis showed significant differences among the different treatments varying from (16.79 to 25.16 t ha^{-1}) of radish and byproduct (leaves) yield were produced in Belwa site. In general all the treatments were superior to the farmers practice. The maximum yield (25.16 t ha^{-1}) of radish at Belwa was obtained when 15 t ha^{-1} compost was applied in combination with 60:30:20 N: P_2O_5: K_2O kg ha^{-1} from mineral fertilizers.

Table: 3. Location- Sarada Batase VDC, Kavre District, Hill Site

S. No.	Crops		Yield t ha^{-1} (Average of 4 Farmers)		
			T1	T2	T3
1	Cauliflower	Flower	19.35	18.81	17.03
		Leaves	10.10	11.32	9.03
2	Radish	Tuber Leaves	20.25	18.63	16.98
			11.83	12.16	10.76

Table: 4 Yield of lentil harvested from integrated nutrient management demonstration trial at two sites.

Site		Yield kg ha^{-1} (Average of 4 Farmers)			
Belwa					
	Grain	T_1	T_2	T_3	T_4
		751.83	807.99	907.83	645
Sarada Batase					
	Grain	200	155	184	140
	Straw	580	760	860	510

Source: Bhattarai et al. 2002.

Table: 5 Nutrient Balance Sheet of Different Vegetables at Belwa, Parsa District

Crop	Treatments	Total Nutrient Supply (NPK kg ha^{-1})	Yield Dry Weight (t ha^{-1})	Total Nutrient Uptake (NPKkgha^{-1})	Balance (NPK kg ha^{-1})
Cabbage					
	T1	546.45	3.33	294.98	+ 251.47
	T2	383.22	2.89	284.44	+ 98.78
	T3	220.00	2.74	162.71	+ 57.29
	T4	-	1.75	166.74	- 166.74
Radish					
	T1	639.0	3.56	328.24	+ 310.76
	T2	384.45	2.74	239.0	+ 82.00
	T3	130	3.09	283.8	- 153.81
	T4	-	2.62	321.39	- 63.08

Source: Bhattarai et al. 2002.

Note: T_1. Compost 30 t ha^{-1}; T_2. Compost 15 t ha^{-1} + 60:30:20 N: P_2O_5: K_2O kg ha^{-1}; T_3. 120:60:40 N: P_2O_5: K_2O kg ha^{-1}; T_4. Farmer's practice (3.5 t FYM ha^{-1})

Lentil

Grain yield of lentil at both the locations are summarized in Table-4. Maximum grain yield of lentil (907.83 kg ha^{-1}) was obtained in the plots treated with recommendation dose of mineral fertilizer and lowest (751.83 kg ha^{-1}) in compost applied plots at the rate of 20:40:30 N: P_2O_5: K_2O kg ha^{-1} and 30 t ha^{-1} respectively at Belwa however all the treatments were superior in yield than farmers treated plots. There is a big variation in farmer to farmer when we visualized ranges of yield of lentil at Belwa. Similarly, the nutrient balance sheet of different vegetable crops at different treatments is given in Table 5 and 6, which shows that application of high quality compost (T1) has remarkably higher positive nutrient balance.

Table: 6 Nutrient balance sheet of different vegetables at Sarada Batase, Kavre District

Crop	Treatments	Total Nutrient Supply (NPK kg ha^{-1})	Yield Dry Weight (t ha^{-1})	Total Nutrient Uptake (NPK kg ha^{-1})	Balance (NPK kg ha^{-1})
Cabbage					
	T1	604.5	6.89	736.39	-131.891
	T2	412.25	6.15	691.85	-271.60
	T3	220.0	5.45	722.16	-502.16
Radish					
	T1	807.0	2.52	187.71	+619.29
	T2	468.5	2.88	277.08	+191.42
	T3	130.0	3.08	278.53	-148.53

Source: Bhattarai et al. 2002.

Note: T_1. Compost 30 mt ha^{-1}; T_2. Compost 15 mt ha^{-1} + 60:40:30 N: P_2O_5: K_2O kg ha^{-1}; T_3. 120:60:30 N: P_2O_5: K_2O kg ha^{-1}

Findings from other research

Soil Science Division has also conducted a pot experiment on maize and wheat crop to observe the effect of ordinary compost and vermicompost. The experimental results have given below in Table-7 and 8.

Khadka et. al. (2007) was conducted an experiment on potato crop and the three years results have shown that the combination of 50: 50: 30: N: P_2O_5: K_2O kg ha^{-1} chemical fertilizer and 10 t. FYM ha^{-1} gave highest potato tuber yield as of 21.9 t. ha^{-1} (Table 9).

The potato crop yielding 20 tons ha^{-1} found to be removing 140 kg N, 40 kg P_2O_5 and 90 kg K_2O ha^{-1} (Joshy, 1997). The progressive farmers, at present, use 100: 100: 60 kg ha^{-1} N, P_2O_5 and K_2O respectively + 20 tons FYM ha^{-1} and the average yield obtained is 12.5 tons ha^{-1} only (Khadka, 2007).

Table: 7 Effects of Vermicompost and Ordinary Compost on Maize

S. N.	Treatment	Plant height (cm)	Dry wt. plants (g/5plants)	Grain (N %)	Cub with stover wt. (g/5 plants)
1	Vermicompost	164	90.79	2.84	282.52
2	Vermicompost+Soil (1:1)	143	23.66	2.27	160.65
3	Soil	79	1315	0.54	47.44
4	Compost	134	25.41	0.96	99.33
5	Compost + Soil (1:1)	81	14.00	0.81	43.44

Source: Bhattarai et al. 2002.

Table: 8 Effects of Vermicompost and Ordinary Compost on Wheat

S. N.	Treatment	Plant height (cm)	Grain (g/5 plants)	Straw wt. (g/5 plants)
1	Vermicompost	58.4	7.00	16.37
2	Vermicompost + Soil (1:1)	57.2	5.54	10.85
3	Soil	41.9	2.00	5.91
4	Compost	53.4	4.29	8.74
5	Compost + Soil (1:1)	51.5	3.61	7.36

Source: Bhattarai et al. 2002.

Table: 9 Potato tuber production (kg ha^{-1}) as affected by organic, inorganic and micronutrient fertilizers

Treatment	2002	2003	2004	Mean
Control (No fertilizer application)	10550 e	6825 b	6716 d	8029 e
100: 100: 60 N: P_2O_5: K_2O kg ha^{-1}	17090 d	14600 a	16290 bc	16000 d
3. 20 tons ha^{-1} FYM	18670 cd	12720 a	17900 bc	16430 cd
½ dose of N: P_2O_5: K_2O and FYM	30240 a	13910 a	21650 a	21930 a
Zn 5.5 kg +100: 100: 60 N: P_2O_5: kg ha^{-1}	24400 b	15930 a	18350 b	19560 b
6. Cu 6.3 kg + 100: 100: 60 N: P_2O_5: K_2O kg ha^{-1}	23170 bc	14940 a	15000 c	17700 bcd
B 1.13 kg + 100: 100: 60 N: P_2O_5: K_2O kg ha^{-1}	25970 ab	14960 a	15830 bc	18920 b
Mo 1.10 kg +100: 100: 60 N: P_2O_5: K_2O kg ha^{-1}	22260 bc	14090 a	17770 bc	18040 bc
Combination of T5 +T6 + T7 + T8 + 100: 100: 60 N: P_2O_5: K_2O kg ha^{-1}	22490 bc	14460 a	15710 bc	17560 bcd
Mean	21650	13604.48	16136.03	17130.20
C.V. (%)	14.43	16.44	11.88	14.47
LSD at 0.05	4560	3263	2799	2018
S.E.D:	1562.40	1118.00	958.82	715.72

Source: Khadka, 2007

CONCLUSION

The integrated plant nutrient system (IPNS) has an integral part of nutrient management for Nepalese farming system to boost crop productivity. Soil quality could be deteriorated particularly physico-chemical properties as well as microbial activities in the soil system if continuously application of chemical fertilizers with out addition of organic manures On the other hand, organic manures alone could not meet the nutrient requirement of the crops. The integrated plant nutrient system needs further research and extension efforts to fully amalgamate it into the national extension system. This should be a gradual process and lesson learnt so far should be incorporated in the future programmed. It is important to emphasize that IPNS should gradually be included into comprehensive package of "integrated crop management (ICM)" which will reduce some duplications, minimize the resources use and farmer's time and efforts, and can reach to the farmers through the existing extension system and with a single channel of delivery.

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