Chemical and Organic Fertilizers Application on Yield, Nutrient Uptake and Nitrogen Use Efficiency of Chinese Cabbage (*Brassica pekinensis*) in Different Soils

Soe Sandar Aung[1*], Aung Kyaw Myint[2], Toe Toe Maw[3], Kyaw Kyaw Win[4], Kyaw Ngwe[3]

Abstract

A questionnaire survey and a set of field experiments were conducted in Heho Horticulture Farm, DOA, Kalaw Township, Southern Shan State to explore the farmer practices on Chinese cabbage production, and to investigate the effect of different fertilizers on yield, nutrient uptake and nitrogen (N) use efficiency of Chinese cabbage in peat soil and red soil during the winter season, 2016-2017. The experimental design was randomized complete block design with four replications. The treatments were T1 (control), T2 (20 t cowdung manure (CM) ha^{-1}), T3 (200 kg N ha^{-1}), T4 (160 kg N ha^{-1}), T5 (120 kg N ha^{-1}), T6 (100 kg N ha^{-1} + 10 t CM ha^{-1}), T7 (80 kg N ha^{-1} + 10 t CM ha^{-1}), T8 (60 kg N ha^{-1} + 10 t CM ha^{-1}) and T9 (farmer practice, FP; 104 kg N ha^{-1} + 11 t CM ha^{-1}).

According to the survey results, all farmers used cowdung manures and compound fertilizers (15:15:15) in Chinese cabbage production. Generally, 2.5 – 5 bags of 50 kg urea ha^{-1} and 5 – 7.5 bags of 50 kg compound fertilizer ha^{-1} were applied. In peat soil, T3 gave the highest yield but, the highest apparent N recovery (ANR) was obtained from the lower N application rates (T4 and T5). FP gave lower yield compared to T3 and T4. In red soil, the highest yield, nutrient uptake and ANR were observed from T4. T6 might be suitable fertilizer application practice in red soil due to its high yielding capacity and high Benefit-cost ratio (BCR). In respective treatments, yield (fresh weight), N uptake and ANR were greater in red soil compared to peat soil.

Key words: **Chinese cabbage, combined application, nutrient uptake, Apparent N recovery (ANR), organic manure, peat soil, red soil**

Introduction

Vegetable crops are important from economic point of view as their maturity period from planting to harvest is short (Patel 2010). In Myanmar, vegetable sown areas reached 1,403,000 acres and harvested 1,399,000 acres in 2015-2016 (CSO 2016), among them 195,025 acres were cultivated in Shan State. Chinese cabbage (*Brassica pekinensis*) belongs to the family Cruciferae is an important leafy, herbaceous vegetable crop (Rashid 1999). It is one of the major cultivated crops and popular among the local farmers in Shan State. It contains a valuable source of calcium, crude fiber and vitamin C (Thapa and Prasad 2011).

Different soil types, such as red earths and yellow earths, lateritic soils, degraded soils and peat soils are found in Southern Shan State (Tin Maung Aye 2001). Generally, Chinese cabbage is cultivated in peat soil and red soil which are mostly dominant in Shan state. The peat land area in Myanmar is 122,800 ha (Lo and Parish 2013) while *28% of land in Myanmar are ferralsols or red soil (MEIP 2016).*

Nutrient management with proper fertilizer rates and application practice is crucial to attain larger production and quality yield for any crop (Easmin *et al*. 2009). Nitrogen (N) has intense effect on the number of folder leaves and adequate supply is essential for vegetative growth, head formation for progressively increasing the marketable yield for Brassica (Obreza and Vavrina 1993). However, the excessive application of chemical fertilizers causes degradation of soil properties, high input cost and may impose to environmental problem (Oguzar

[1]Master Candidate, Department of Soil and Water Science, Yezin Agricultural University
[2]Yezin Agricultural University (Kyaukse Campus)
[3]Department of Soil and Water Science, Yezin Agricultural University
[4]Department of Agronomy, Yezin Agricultural University
*Corresponding author: soesandaraung355@gmail.com

2007). Qui *et al*. (2013) stated that organic fertilizer is gaining importance in agriculture and it can increase crop yield and quality. Organic fertilizers improve soil structure, moisture holding capacity, diversity and activity of soil organisms (FAO 2005).

Zerihun and Haile (2017) indicated that the use of organic fertilizers combined with inorganic sources increased nutrient availability, optimized the soil environment and improved crop productivity. The combined application of organic and chemical fertilizers can lead to increase in availability of nutrients, high positive effect on microbial biomass, sustainable crop yield and promote the environmental quality (Patra *et al*. 2000). Based on the above background concept, this study was conducted 1) to explore the farmer practices on Chinese cabbage production in Heho, Kalaw Township in Southern Shan State, and 2) to investigate the effect of different fertilizers application on yield, nutrient uptake and Apparent N recovery of Chinese cabbage in different soils.

Materials and Methods

A questionnaire survey of Chinese cabbage growers was carried out at three villages, namely Innkhaung, Ywataw and Poneinn in Heho area, Kalaw Township, on October, 2016. The sample size was 36, such as 12 farmers from each village. The collected data were cultural practices, application rate and kinds of fertilizer and manure and problems of encountered by farmers in Chinese cabbage cultivation. Based on the survey results, Field experiments (peat soil and red soil) were conducted in Heho Horti Farm, DOA, Kalaw Township, from December, 2016 to March, 2017. Prior to the field experiments, physiochemical properties of soils were analyzed and shown the results in table 1. Field experiments were laid out in the Randomized Complete Block (RCB) Design with four replications. Plant spacing was 20 cm × 30 cm, the plot size was 2 m × 4 m with 1 m space between the treatment plots and replicated plots, and total experimental area was 690 m^2. The treatments were T1 (control), T2 (20 t cowdung manure (CM) ha^{-1}), T3 (200 kg N ha^{-1}), T4 (160 kg N ha^{-1}), T5 (120 kg N ha^{-1}), T6 (100 kg N ha^{-1} + 10 t CM ha^{-1}), T7 (80 kg N ha^{-1} + 10 t CM ha^{-1}), T8 (60 kg N ha^{-1} + 10 t CM ha^{-1}) and T9 (Farmer Practice, FP, based on survey result).

Cultural practices

Cow dung manure used in the experiments was analyzed for chemical composition before experiments. Well decomposed cowdung manure was applied as basal before the transplanting. In all mineral N application treatments, half dose of N was applied as basal and the remaining half was equally split at 10 and 24 days after transplanting (DAT). Similarly, compound fertilizer in FP was also applied half dose as basal and the remaining half into

Table 1. Physicochemical properties of experimental soils

Characteristics	Contents (Rating)	
	Peat soil	Red soil
Sand (%)	83	69
Silt (%)	7	5
Clay (%)	10	26
Texture class	Loamy Sand	Sandy Clay Loam
pH	4.9	6.9
EC (dS m^{-1})	0.22	0.14
CEC (meq 100 g^{-1})	46.27	18.23
Organic carbon (%)	2.34	1.35
Total N (%)	0.09	0.06
Total P (%)	0.34	0.36
Total K (%)	0.36	0.63
Available N (mg kg^{-1})	127 (very high)	78 (medium)
Available P (mg kg^{-1})	5.4 (low)	3.6 (low)
Available K (mg kg^{-1})	72 (low)	100 (low)

two equally splits at 10 and 24 DAT. The seedlings were watered early morning before transplanting to the field. Healthy, 25-day-old seedlings were selected to transplant. The insecticide application was done twice in a week as a matter of routine work from transplanting up to the end of head formation. Watering was done by using a pump and hose whenever it is necessary.

Dry matter, yield and nutrient uptake of Chinese cabbage

The fresh weight and dry matter increments were also recorded throughout the cultivation season at 40 DAT, 50 DAT, 60 DAT and harvest in both experiments. Three plants in each unit plot were selected at random and cut to determine fresh weight immediately and dry weight was taken after drying (5 days of air-dry followed by 2 days oven-dry at 60°C). Yield of Chinese cabbage was taken from each plot, by taking 12 plants from a selected harvest area of 1.2 m × 0.6 m (0.72 m^2). The sample were gathered and measured for fresh weight immediately.

Total N, P and K content of the harvest plant samples were analyzed for nutrient content of Chinese cabbage. Oven-dried plant samples from the harvest sampling were taken, cut into small pieces with scissors and ground to pass 2 mm sieves in a grinder.

The plant samples were digested by using modified Kjeldahl Digestion method (H_2SO_4-H_2O_2 Digestion, Ohyama *et al*. 1991) to determine total N, P and K. Total nitrogen was analyzed by using N distillation unit (VAP-450, Gerhardt, Germany), total P, by using Ascorbic acid methods with a spectrophotometer (Murphy and Riley 1962), and total K, by using Atomic absorption spectrophotometer (AAS). Available N was analyzed by 2 N KCl extraction, available P, by 0.5 M $NaHCO_3$ extraction and available K, by 1 N Ammonium acetate extraction.

Calculations

Nutrient uptake, apparent N recovery, agronomic efficiency and benefit cost ratio were calculated by using the following formulas.

$$\text{Nutrient uptake } (\text{g plant}^{-1}) = \frac{\text{Nutrient content (\%)} \times \text{Dry matter yield}}{100} \quad \text{(Roy 2007)}$$

$$\text{Apparent N recovery (\%)} = \frac{\text{N uptake Fertilizer - N uptake Control}}{\text{fertilizer N applied}} \times 100$$

$$\text{Agronomic efficiency} = \frac{\text{Yield Fertilizer} - \text{Yield Control}}{\text{Fertilizer N applied}}$$

(Craswell and Godwin 1984)

$$\text{Benefit} - \text{cost ratio} = \frac{\text{Total Gross Return}}{\text{Total Variable Cost}}$$

(Olson 2009)

Statistical analysis

All the collected data were analyzed using ANOVA with Statistix 8 software. Means of different treatments were separated by Least Significant Difference (LSD) at 5 percent probability level.

Results and Discussion

Questionnaire Survey on Chinese cabbage production

In this study, most of the respondents answered that they have many reasons for selecting Chinese cabbage crops. Regarding more than 50% of the respondents, the main reasons of their selection of Chinese cabbage are low input cost, easiness to grow and other reasons such as short duration and minimum crop failure (Figure 1). In this study area, all respondents answered that there was no problem accessibility with the availability and transportation of fertilizers and they could effort to spend for crop production in adequate amount (Figure 2). In addition, fertilizer indication is adopted by 61% respondents but it is not by 39% respondents. Farmers use cowdung manure, chemical fertilizers such as urea and compound fertilizers (e.g. 15:15:15 of N:P:K) in Chinese cabbage cultivation. One handful of cowdung manure (about 100 g) per hole (at the rate of 11 ton cowdung ha^{-1}) was applied. The amount of 50 kg bags compound fertilizer in Chinese cabbage production are 5 – 7.5 bags of 50 kg ha^{-1} (44% respondents), 7.5 – 10 bags of 50 kg ha^{-1} (33% respondents). Very high amount as large as 10 – 12.5 bags of 50 kg ha^{-1} (14% respondents) and 17.5 – 21.5 bags of 50 kg ha^{-1} (3% respondents) on the other hand, as low as 2.5 – 5 bags of 50 kg ha^{-1} (6% respondents) were also observed (Figure 3 (A)).

The different rates of urea fertilizer were used in Chinese cabbage cultivation in the study area. Using very high amount of urea, such as 7.5 – 10 bags of 50 kg ha^{-1} and 12.5 – 15 bags of 50 kg ha^{-1} were observed (Figure 3(B)). But, 52% of total respondent farmers used 2.5 – 5 bags of 50 kg urea ha^{-1}. Large amount, at the rate of 12.5 – 15 bags of 50 kg urea ha^{-1} were also observed at 6% respondent. Moeskops *et al*. (2010) reported that, in developing countries, the excessive fertilizer N rates were

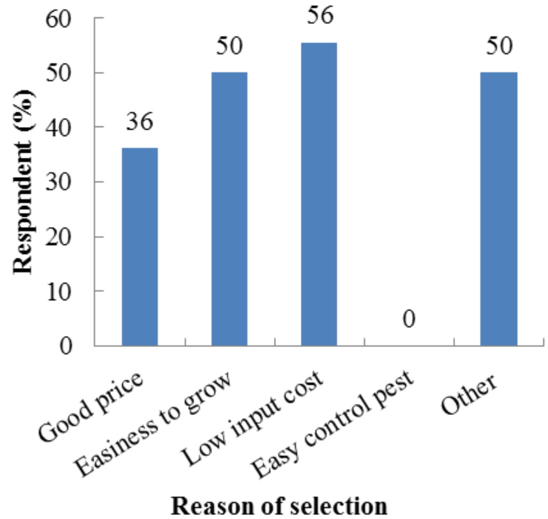


Figure 1. Reasons for selection of Chinese cabbage in Heho area

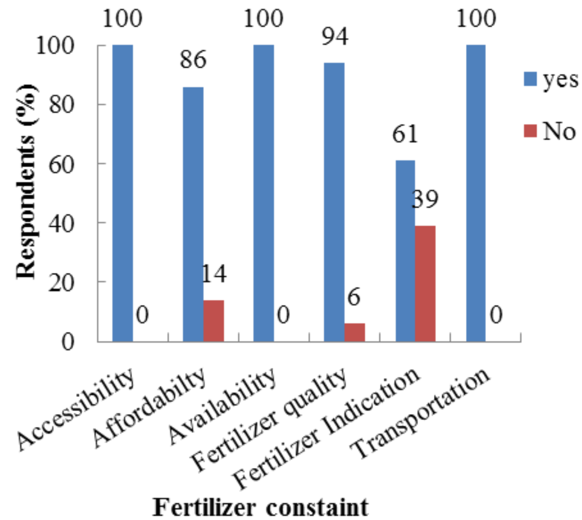
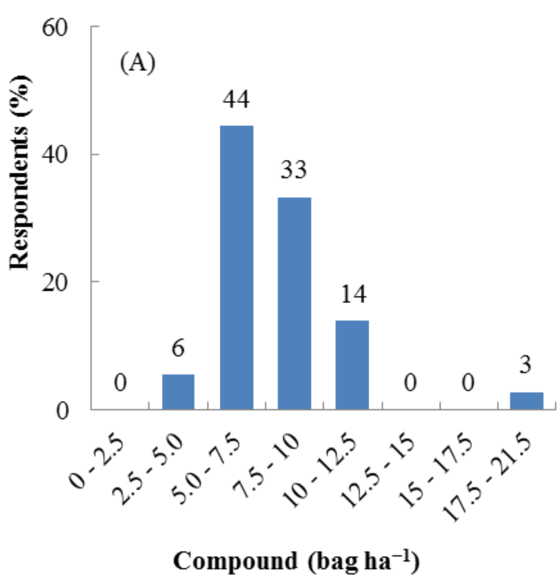


Figure 2. Constraints in using of fertilizers for Chinese cabbage production in Heho area



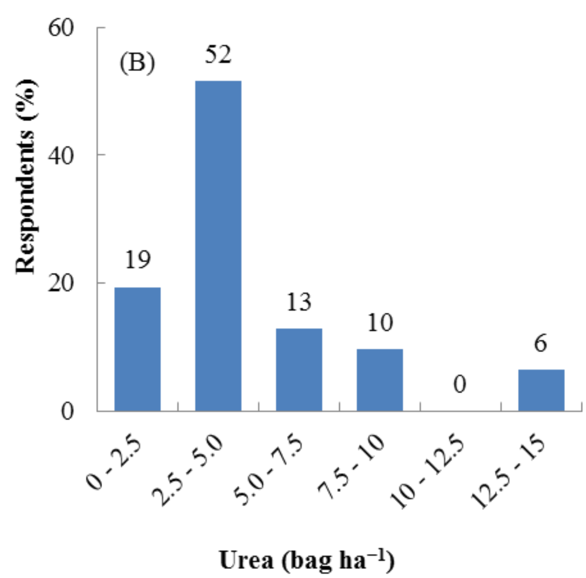


Figure 3. Amounts of (A) Compound fertilizers and (B) Urea fertilizers used in Chinese cabbage production in Heho area

common in vegetable gardens and fields to attain high yield. However, the extremely large amounts of fertilizer were not observed in this study.

Field Experiments

Fresh weight

Fresh weights of Chinese cabbage in all treatments are drastically increased from 40 DAT until harvest except T8 and then slightly decreased after 60 DAT (Figure 4 (A)). At harvest, the highest fresh weight was recorded from T9 (0.91 kg plant^{-1}) (farmer practice) followed by chemical only application treatments, T4 (0.86 kg), T3 (0.84 kg) and T5 (0.85 kg) those were statically similar.

Similarly, fresh weights of Chinese cabbage in all treatments gradually increased from 40 DAT to harvest (Figure 4 (B)). Sampling at the harvest, fresh weight ranged from 0.99 kg plant^{-1} to 1.27 kg plant^{-1}. The maximum fresh weight was observed in T4 (1.27) while the minimum in T1 (0.99) and T2 (0.1). The highest N application produced second highest fresh weight at harvest. Boroujerdnia and Ansari (2007) stated that increasing N fertilizer rate from 120 kg N ha^{-1} to 180 kg N ha^{-1} increased fresh weight of Chinese cabbage but, above 180 kg N ha^{-1} did not. Fresh weights of Chinese cabbage in all treatments were higher in red soil compared to peat soil and that could be due to the presence of high water table which is one of the factor that limit the root growth in peat soils.

Dry weight

Dry weights of Chinese cabbage increased with increasing days of transplanting from 40 DAT to harvest throughout the season in peat soil (Figure 5 (A)). At harvest, the maximum dry weight was obtained from T9 (35.94 g plant^{-1}) while the minimum from T1 (21.17 g plant^{-1}) followed by T2 (25.77 g plant^{-1}) and T4 (25.58 g plant^{-1}). Different from fresh weight data, the high application of N fertilizer (organic or chemical) might decrease dry weight of Chinese cabbage. The similar results were reported by Sultana (2007) who stated that dry matter content of Chinese cabbage decreased by increasing N rates.

Dry weights of Chinese cabbage in red soil gradually increased from 40 DAT to harvest and presented in Figure 5 (B). At harvest the dry weights were not statically different, but the highest dry weight recorded from T9 (FP) (52.6 g plant^{-1}) followed by T3 (51.4 g plant^{-1}) while the lowest dry weight recorded from T1 (40.3 g plant^{-1}). As with fresh weight data, dry weights of Chinese cabbage were higher in red soil compared to peat soil.

Yield

Harvesting was done at 70 DAT in peat soil while 65 DAT in red soil depend on their maturity. The highest yield was obtained from T3 (13.63 kg m^{-2}) and the lowest yield was obtained T1 (4.06 kg m^{-2}) which was statistically similar with T2 (5.71

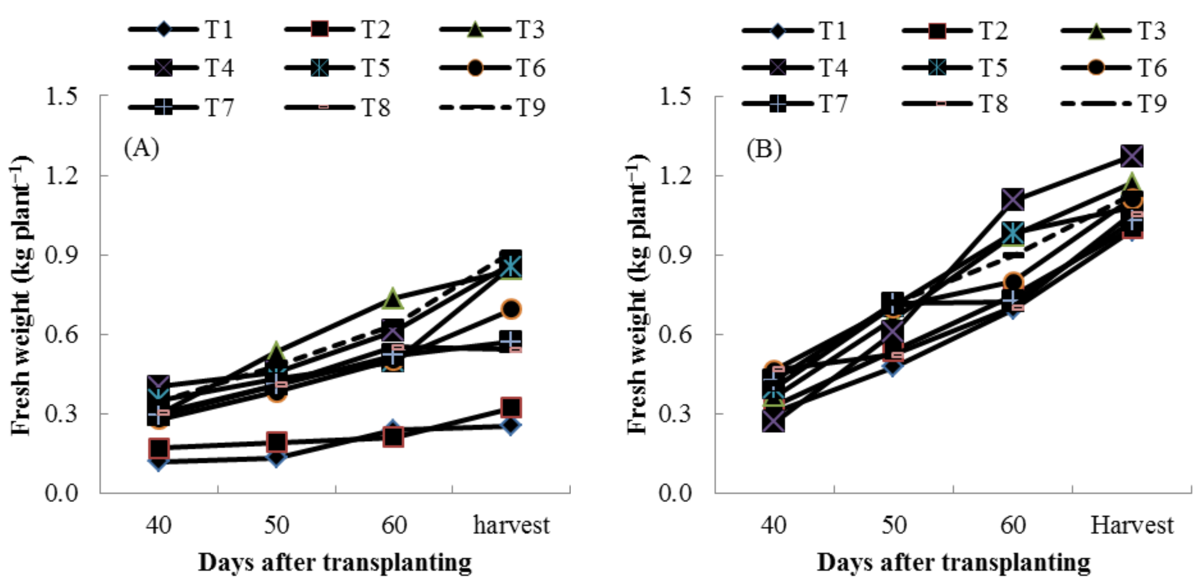
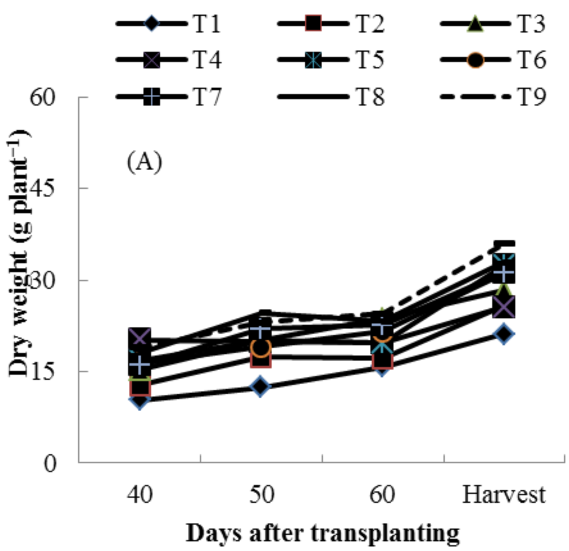


Figure 4. Fresh weights of Chinese cabbage as affected by organic and chemical fertilizers in (A) peat soil and (B) red soil during winter season, 2016-2017



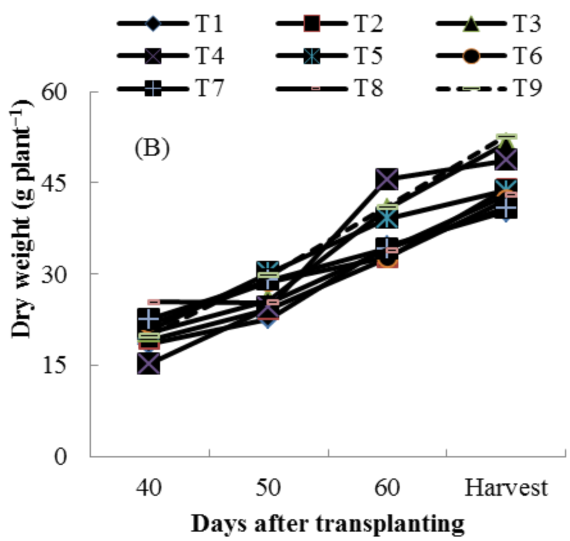


Figure 5. Dry weights of Chinese cabbage as affected by organic and chemical fertilizers in (A) peat soil and (B) red soil during winter season, 2016-2017

kg m^{-2}) in peat soil (Table 2). High fresh weight yield in T3 could be due to split application of N fertilizer which could increase efficiency of N utilization. Krezel and Kolota (2008) stated that crop yield improved at 200 kg N ha^{-1} by the changing N application practice from single pre-vegetation to split application (100+50+50).

The yields of Chinese cabbage in red soil were higher than those in peat soil (Table 2). The highest yield was obtained from T4 (160 kg N ha^{-1}) followed by T6 (17.05 kg m^{-2}) and T9 (17.03 kg m^{-2}) (FP). The lowest yield was recorded from T1 (control). These results indicated that the high rates of chemical N fertilizer or combined application of organic and chemical fertilizer increased the yield of Chinese cabbage. Easmin *et al*. (2009) indicated that to attain considerable production and quality yield, it is necessary to ensure the availability of essential nutrient components, growth and yield of cabbage were remarkably influenced by the application of organic and inorganic nutrients.

Nutrient uptake

Applied chemical N fertilizers or combination of organic and chemical fertilizers increased nutrients uptakes of not only N but also P and K in Chinese cabbage when those were compared to control (no N application) (Table 3). The highest N uptake was observed from T4 (0.94 g plant^{-1}) while the lowest from T1 (0.25 g plant^{-1}). Although the highest rate of N fertilizer was used in T3, the highest N uptake was observed from the second highest rate of N (T4). However, the amount of N uptake in T3 and T4 were not statistically different in each other. N uptake always increased with increasing N rates (Riley and Vagen 2003). The highest P uptake was observed from T4 (0.19 g plant^{-1}) which was statically identical with T5 (0.19 g plant^{-1}), T9 (0.19 g plant^{-1}) and T3 (0.18). The lowest was obtained from T1 (0.09 g plant^{-1}). The application of higher dosages of NPK, might have led to better root development, better nutrient transportation and water uptake and deposition of nutrients and therefore, P uptake by plant increased gradually with increasing levels of inorganic fertilizers (Singh *et al*. 2013). K uptake ranged from 1.48 g plant^{-1} to 0.55 g plant^{-1}. The highest K uptake was observed from T5 (1.48 g plant^{-1}) followed by T4 (1.30 g plant^{-1}), T3 (1.26 g plant^{-1}), T6 (1.20 g plant^{-1}) and T9 (1.17 g plant^{-1}) while the lowest from T1 (control). Among three levels of N only application treatments, the lowest N applied rate could give the highest K uptake. Moreover, compared to chemical only applications, combined treatments increased the optimum K uptake. Eghball *et al*. (2002) reported that manure can be used as K fertilizers because K availability from manure is nearly 100%.

Nitrogen uptakes of Chinese cabbage among treatments were highly significantly different but, no significantly different among treatments for P and K uptake in red soil (Table 3). The highest N uptake was obtained from T9 (2.17 g plant^{-1}) fol-

Table 2. Organic and chemical fertilizer application on yield (fresh weight), apparent N recovery (ANR), agronomic efficiency (AE) and benefit-cost ratio (BCR) of Chinese cabbage in different soils, 2016-2017

Treat-ment	Yield (kg m^{-2})		Apparent N recovery (%)		Agronomic efficiency		Benefit-cost ratio	
	Peat soil	Red soil	Peat soil	Red soil	Peat soil	Red soil	Peat soil	Red soil
T1	4.06 e	14.46	-	-	-	-	1.00 e	3.31
T2	5.71 e	15.2	12 d	24 c	2.66 d	2.15	1.23 e	3.07
T3	13.6 a	16.35	34 bc	45 bc	4.27 cd	6.65	2.89 a	3.27
T4	13.2 ab	17.53	52 a	82 a	3.30 cd	6.32	2.85 a	3.56
T5	12.3 abc	16.44	38 ab	63 ab	11.18 a	3.41	2.70 ab	3.39
T6	11.0 bcd	17.05	20 cd	41 bc	5.83 bcd	1.09	2.29 bcd	3.34
T7	10.2 cd	15.72	29 bc	29 c	6.56 bc	0.35	2.14 cd	3.11
T8	9.44 d	15.26	23 bcd	41 bc	8.57 ab	1.99	2.00 d	3.04
T9	12.5 abc	17.03	25 bcd	51 bc	6.53 bc	5.45	2.52 abc	3.23
$LSD_{0.05}$	2.40	3.08	0.17	0.31	3.65	6.7	0.52	0.63
Pr > f	**	ns	**	*	**	ns	**	ns
CV %	16.09	13.12	40.14	44.39	40.62	132.99	16.40	13.23

Table 3. Nutrient uptakes of Chinese cabbage by the application of organic and chemical fertilizers in peat soil and red soil during winter season, 2016-2017

Treatment	Peat soil			Red soil		
	N uptake	P uptake	K uptake	N uptake	P uptake	K uptake
T1	0.25 d	0.09 c	0.55 d	1.03 c	0.24	1.78
T2	0.45 cd	0.13 bc	0.78 cd	1.44 bc	0.24	1.72
T3	0.81 ab	0.18 a	1.26 ab	1.77 ab	0.25	1.71
T4	0.94 a	0.19 a	1.30 ab	2.12 a	0.26	1.97
T5	0.62 bc	0.19 a	1.48 a	1.67 ab	0.24	1.92
T6	0.59 bc	0.16 ab	1.20 ab	1.72 ab	0.25	1.79
T7	0.69 bc	0.16 ab	1.09 bc	1.47 bc	0.22	1.71
T8	0.56 c	0.17 ab	1.12 b	1.58 b	0.21	1.82
T9	0.80 ab	0.19 a	1.17 ab	2.17 a	0.25	2.55
$LSD_{0.05}$	0.2471	0.0468	0.3124	0.5147	0.0775	0.6845
Pr>f	**	**	**	**	ns	ns
CV%	26.7	20	19.3	21.3	22.5	24.9

lowed by T4 (2.12 g plant^{-1}), T3 (1.77 g plant^{-1}), T6 (1.72 g plant^{-1}) and T5 (1.67 g plant^{-1}) while the lowest in T1 (1.03 g plant^{-1}). Nitrogen uptakes in red soils in all treatments were higher compared to the treatments in peat soils. This might be due to loss of N by de-nitrification in peat soil which has high water table. Van Kessel *et al*. (2000) reported that in aerobic soils, about 92% of urea in manure was mineralized within 1st year. Manure N mineralization depends on the N constituents in manure.

Apparent N recovery (ANR)

Apparent N recovery is one of the measures to estimate N use efficiency of applied fertilizers. The highest ANR was obtained from T4 (52%) followed by T5 (38%) while the lowest ANR from T2 (12%) in peat soil (Table 2). In this regards, the highest N rate did not give the highest ANR however lower N rates at 160 kg N ha^{-1} gave the highest ANR. VanEerd (2005) found that ANR of cole crops decreased as fertilizer N input increased.

It is important to improve ANR of crop plants because the economic costs of fertilization and the potential environmental damage of excessive fertilization have to be reduced in significant amount (Good *et al*. 2004). The apparent N recoveries of Chinese cabbage in red soil were significantly different among treatments (Table 2).

Agronomic efficiency (AE)

Agronomic efficiency of Chinese cabbage in peat soil was highly significantly different among treatments (Table 2). Among the treatments, T5 (the lowest N rate among chemical treatments) gave the highest AE followed by T8 (the lowest N rate among combined treatments) while the lowest from T2. These results showed that the treatments in lowest chemical fertilizer and combined application of organic and chemical fertilizers gave higher AE. Similar results were reported by Shahzad *et al*. (2010) who stated that the used of increasing N fertilizer rate decreased AE.

Agronomic efficiencies of Chinese cabbage were not significantly different among treatments in red soil (Table 2) but, highest AE in T3 while the lowest in T7.

Benefit cost ratio (BCR)

There were highly significantly different among treatments for BCR in peat soil (Table 2). The highest BCR was obtained from T3 (2.89) and T4 (2.85) while the lowest from T1 (1.00) and T2 (1.23). This result pointed out the higher rate of chemical fertilizer up to 200 kg N ha^{-1} increased BCR. Sharma *et al*. (2004) reported that increasing the levels of NPK fertilizers significantly improved net return of red cabbage (*Brassica*) and BCR of 5.17.

In agriculture, crops and cropping practice with B:C higher than 1.5 is regarded as profitable (Raj 2011). According to his report, all treatments in red soil and all treatments except T1 and T2 in peat soil can be assumed to be profitable fertilizer rate and practice due to their higher BCR value (Table 2).

Conclusion

In Heho area, farmers select Chinese cabbage due to the following reasons: minimum failure of crop, easiness to grow, short duration and low input cost. Farmers used more compound fertilizers (15:15:15) compared to straight fertilizers. Generally, all farmers in Heho area used combination of organic (cowdung manure) and chemical fertilizers in vegetable production. There were no constraints in fertilizer use by farmer in Heho area for vegetable production. In peat soil, the highest N (200 kg N ha^{-1}) gave the highest yield but, the highest apparent N recovery (ANR) was obtained from the lower N application rates (T4 and T5). Farmer practice (T9) fertilizer application produced lower yield compared to T3 and T4 in peat soil. In red soil, the highest yield, nutrient uptake and ANR were observed from T4 (160 kg N ha^{-1}) which was statistically similar to T6 (100 kg N ha^{-1} + 10 t CM ha^{-1}) and T9 (FP). T6 might be suitable fertilizer application practice in red soil due to its high yielding capacity and high BCR. In respective treatments, yield, N uptake and ANR were greater in red soil compared to peat soil and it might be due to poor drainage of peat soil.

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References

Boroujerdnia, M. and N. A. Ansari. 2007. Effect of different levels of nitrogen fertilizer and cultivars on growth, yield and yield components of romaine lettuce *(Lactuca sativa* L*.).* Middle Eastern & Russian Journal Plant Science Biotech 1(2): 47-53.

Craswell, E. T. and D. C. Godwin. 1984. The efficiency of nitrogen fertilizers applied to cereals grown in different climates. In: Tinker P.B. and Lauchli A. (eds.) Advances in Plant Nutrition, 1: 1–55.

CSO (Central Statistical organization), Myanmar statistical Year Book 2016. The Government of the Republic of the Union of Myanmar: Ministry of National Planning and Economic Development.

Easmin, D., M. J. Islam and K. Begum. 2009. Effect of different levels of nitrogen and mulching on the growth of Chinese cabbage(*Brassica campestris* var. *Pekinensis*); Progress. Agric. 20 (1 & 2): 27-33.

Eghball, B., J W. Brian, E. G. John, and A. E. Roger. 2002. "Mineralization of Manure Nutrients". Journal of Soil and Water Conservation, 57(6): 470-473.

FAO (Food and Agriculture Organization) 2005. The importance of soil organic matter. In: Chapter 5 Creating drought resistant soil. pp.35

Good, A. G., A. K. Shrawat and D. G. Muench. 2004. Can less yield more? Is reducing nutrient input into the environment compatible with maintaining crop production? Trends in Plant Science 9: 597 – 605.

Krezel, J. and E. Kolota. 2008. The effect of nitrogen fertilizers on yield and biological value of Chinese cabbage grown from seedlings for autumn harvest. Journal of elemental, 13(2): 255-260

Lo, J. and F. Parish. 2013. Peatlands and Climate Chane in Southeast Asia. ASEAN Peatland Forest Project and Sustainable managementof Peatland Forests Project. ASEAN Secretariat and Global Environment Centre.

MEIP (Myanmar Environment Information Portal). 2016. Soil types of Myanmar (%), **Theme:** Agriculture and Livestock. http://mya.gms-eoc.org/charts/overview/soil-types-of-myanmar?gid=11. (Accessed in July 27, 2018)

Moeskops, B., Sukristiyonubowo, D. Buchan, S. Sleutel, L. Herawaty, E. Husen, R. Saraswati, D. Setyorini and S. De Neve. 2010. Soil microbial communities and activities under intensive organic and conventional vegetable farming in West Java, Indonesia. Applied Soil Ecology. 45: 112-120.

Murphy, J. and J. Riley. 1962. A modified single solution method for the determination of phosphate in natural waters. Anal. Chim. Acta. 27: 31

Obreza, T. A. and C. S. Vavrina. 1993. Production of Chinese cabbage in relation to nitrogen source, rate and leaf nutrient concentration. Communications in Soil Science and Plant Analysis Journal. 24: 13-14.

Oguzar, N.S. 2007. Effect of palm bunch ash on growth of groundnut. Agronomy journal, 1(2): 59-61.

Ohyama, T., M. Ito, K. Kobayashi, S. Araki, S. Yasuyoshi, O. Sasaki, T. Yamazaki, K. Soyama, R. Tanemura, Y. Mizuno and T. Ikarashi. 1991. Analytical procedures of N, P, K contents in plant and manure materials using H_2SO_4-H_2O_2 Kjeldahl Digestion Method.

Olson K. 2009. Farm Management Principles and Strategies. The textbook of Farm Management: Principles and Strategies.

Patel, H. M. 2010. Effect of different levels of SOC and fertilizer doses on yield of cabbage (*Brassica oleracea* L. var. *capatata*) and soil properties. Ph. D Thesis. Navsari Agricultural University.

Patra, D. D., M. Anwar, and S. Chand. 2000. Integrated nutrient management and waste recycling for restoring soil fertility and productivity in Japanese mint and mustard sequence in Uttra Pradesh, India. *Agriculture, Ecosystems & Environment* 80: 267–275.

Qiu, X., Y. Wang, G. Hu, Q. Wang, X. Zhang, and Y. Dong. 2013. Effect of different fertilization modes on physiological characteristics, yield and quality of Chinese cabbage. Journal of Plant Nutrition, 36: 948-962

Raj A. K. 2011. Economics of organic rice production. The journal of agriculture and environment 12: p 97-103 (Available on: www.nepjol.info/index.php/AEJ/article/ download/ 7569/6152, Retrieved on 2015-05-28 at 12:11)

Rashid, M. M. 1999. Sabjii Biggan. Rashid Publishing. House 94. Old DOHS.Dhaka-1206. p. 248.

Riley, H. and I. M. Vågen. 2003. Critical N-concentrations in broccoli and cauliflower, evaluated in field trials with varying levels and timing of N fertilizer. Acta Horticulturae 627: 241 – 249.

Roy. P. OM. 2007. Influence of organic and inorganic fertilizers on growth yield and quality of spinch. M. Sc Thesis, Bangladesh Agricultural University.

Shahzad J. S., Z. M. Roghayyeh, Y. Asgar, K. Majid, and G. Roza. 2010. Study of agronomical nitrogen use efficiency of durum wheat affected by nitrogen fertilizer and plant density, World Applied Sciences, 11 (6): pp. 674 – 681

Sharma, A., R. Kumar, and M. C. Rana. 2004. Effect of planting geometry and fertilizer levels on growth and yield of red cabbage under high hill dry temperate conditions of north-western Himalayas. Vegetable Science, 31(1): 92-94.

Singh,V. K., K. P. Singh, and R. Ashish. 2013. Influence of chemical fertilizers and biofertilizers on dry matter yield and NPK uptake by Cabbage (*Brassica oleracea* var. capitata Linn.). Asian Journal Horti, 8(2): 568-571.

Sultana, N. 2007. Effect of organic and inorganic fertilizers on growth and yield of Chinese cabbage *(Brassica campestris* var. pekinensis). M.Sc. Thesis. Sher-e-Bangla Agricultural University, Dhaka.

Thapa U. and P. H. Prasad. 2011. Response of nitrogen and phosphorus levels on the growth and yield of Chinese cabbage (*Brassica rapa* (L.) var. *Perkinensis*. *Crop Res*. 42 (1, 2 & 3): 207- 209

Tin Maung Aye. 2001. Developing Sustainable Soil Fertility in Southern Shan State of Myanmar. Ph.D. Thesis, Massey University, New Zealand.

Van Eerd L. L. 2005. Assessing methods to improve nitrogen use efficiency in potatoes and selected cole crops. Ph.D. Thesis, Ridgetown College. University of Guelph.

Van Kessel. J. S., J. B. I. Reeves, and J. J. Meisinger. 2000. Nitrogen and carbon mineralization of potential manure components. Journal of Environmental Quality, 29: 1669-1677.

Zerihun A. and D. Haile. 2017**.** Effect of organic and inorganic fertilizers on the yield of two contrasting soybean varieties and residual nutrient effects on a subsequent finger millet crop. Agronomy Journal: 7(42). pp.3