EFFECT OF RESIDUAL AND ADDED PHOSPHOROUS ON SUNFLOWER (*Helianthus annuus* L.) IN WET SOIL OF SOUTHWESTERN COASTAL BANGLADESH

A THESIS

BY

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DEDICATED TO

MY BELOVED PARENTS AND TEACHERS

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ABSTRACT

Management of fertilizer at optimum rate is one of the most important components in producing maximum yield and profits of any crops. This experiment was carried out in the farmer's field at Pankhali village, Dacope, Khulna, Bangladesh during December 2018 to April 2019 to find out the effect of residual and added phosphorous on sunflower (*Helianthus annuus* L.) in a wet and saline soil of southwestern Bangladesh. The experiment was conducted with randomized complete block design (RCBD) with three replications. Six levels of P (0, 5, 7.5, 10, 12.5, 15 kg ha^{-1}) in the form of triple superphosphate was applied to the previous T. *aman* field treated as residual P and current application of P @ 50 kg ha^{-1} to the sunflower field treated as current P. The result showed that among the residual P levels had no significant effect on the growth, crop phenology, yield attributes and seed yield (residual P from lowest amount, 5 kg/ha, was equal to that of highest amount, 15 kg ha^{-1}). Significant yield difference was only found between zero added P in previous T. *aman* and any of the residual P level. In case of current P application (@ 50 kg ha^{-1}) all the growth, yield contributing parameters and seed yield exhibited highly significant variation. Interaction of residual P and current P application was non-significant in all measured parameters. The result of this experiment revealed that current P application increased the seed yield but the yield gap is only ~0.2 t ha^{-1} in comparison to yield from highest residual P (residual P from 15 kg ha^{-1}). Residual P from previous crop and inherent soil P was sufficient to provide a remunerative seed yield of sunflower in wet soil of southwestern coastal Bangladesh. Residual P fertilizers have an economic significance to farmers because it reduces the need for fertilizer in subsequent years. It might help recommend a P rate for the new crop, sunflower, in this region and reduce the cost of sunflower production.

Key word: Residual P, coastal saline soil, sunflower, fertilizer recommendation

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CHAPTER I

INTRODUCTION

Agriculture is the mainstay of the economy of Bangladesh. The challenges of food security of ever increasing population and to reach the sustainable development goal (SDG) and food supply, increase food production from ever decreasing arable land is necessary. Vertical yield increase by using the current crop varieties has little opportunity but bringing the problem soils (e.g., saline soil) under cultivation and addition of new crop will increase the cropping intensity and crop yield. In the southwestern (SW) Bangladesh a vast area of land remain fallow after harvest single monsoon rice, transplanted (T) *aman*. After harvest of this rice, the lands remain fallow. Agriculture, being the most important livelihood option for the 40 million coastal people of Bangladesh (BBS 2017), cultivation of a second crop after T. *aman* rice will improve their livelihood. The SW coastal region, along with disasters, the agriculture practices are always under threat. Due to the effects of frequent cyclones and storm surges and poor sluice gate management, SW coastal areas usually become waterlogged and salinized. The region, having vast low-lying areas enclosed by man-made polders, is considered to be highly vulnerable to climate change induced hazards. People in the southwestern part of the country can't harvest winter crops because most of the land remains fallow in winter due to late T. *aman* harvest (because farmers cultivate long duration high yielding or local varieties), lands remain wet during the sowing time of winter crops for longer time after T. *aman* harvest (delay in attaining '*Joe*' condition of the soil), lack of rain and fresh irrigation water, soil salinity constraints etc. Among the constraints, excess water in field for longer time during the optimum time of sowing winter crop (November to mid December) is the first constraint that prevents farmers not to cultivate winter crop (Kabir *et al.* 2019). In this situation if farmers cultivate winter crop, that crop face fresh water scarcity for irrigation. If irrigated with saline water, yield reduces even the total crop loss occur. If winter crop is established in wet soil (without waiting for the field capacity moisture), the crop can utilize soil profile water in the early stage, requires less amount of irrigation water with relatively fresh/low salinity (Kabir *et al.* 2019; Bell *et al.* 2019, Paul *et al.* 2019). In this way a winter crop (e.g., sunflower) can be cultivated and cropping intensity can be increased in the SW coastal area (Bell *et al.* 2019).

In Bangladesh, farmers have been cultivating sunflower since 1975 but in a small scale. Now a day it is being cultivated in different part of Bangladesh: Rajshahi, Jashore, Kushtia, Nator, Pabna, Dinajpur, Gazipur and Tangail districts with an average yield of 1.2t/ha. The seed of sunflowers contain 48% - 52% of good quality edible oil and 40% - 50% of protein for consumption. An acute shortage of edible oils has been prevailing in Bangladesh during the last several decades and spending on edible oils and oilseed imports has been increasing to meet the country's demand. In 2014-15, the value of imported oilseeds and edible oils was Tk 27,612 million (US$354 million) and Tk 122,772 million (US$1,574 million) which were 0.87 per cent and 3.88 per cent of the total value of imports (Tk.31, 65,162 million or US$40,579 million), respectively (Bangladesh Bank 2016).

For cultivating winter crops in SW region, some field management techniques were adopted: transplanting and harvesting of short duration rice varieties and using the confined canal water (low salinity, <3 dS/m) and some *rabi* crops (Kabir *et al.* 2019; Bell *et al.* 2019) including sunflower (Paul *et al.* 2019) were cultivated. The cultivation of these crops including sunflower for successively three years (2016 to 2018) opened up the windows to cultivate another crop after T. *aman* for increasing cropping intensity in SW Bangladesh. Sunflower is not included in any cropping pattern and so for the SW region in fallow-fallow-T. *aman* pattern of Bangladesh. More in SW area sunflower is a new crop and new agronomy (fertilizer requirement, cultivation time and techniques, etc.) is thus required. In the Fertilizer Recommendation Guide of Bangladesh, fertilizer recommendation for sunflower for SW region is not available (FRG 2018). Moreover, for many years, farmers have been applying fertilizers including phosphorus (P) to the T. *aman* (as is the only crop in a year), it is not known the status of P and its residue from T. rice to support the growth and yield of sunflower. Thus a T. *aman* experiment was set with six rates of P. After harvest of T. *aman*, sunflower was cultivated in the P treatments plots which were divided into two equal halves: in one half sunflower was with different levels of residual P (if any) only and in other half current P fertilizer was applied to investigate the effect of residual P (if any) and current P application on growth and yield of sunflower.

Phosphorus is the second major nutrient after nitrogen in limiting the crops (including sunflower) (Aduayi *et al.* 2002) production as the amount of readily available phosphorus is very low compared with the total amount of phosphorus in the soil. Plants can only take up phosphorus dissolved in the soil solution, and since most of the soil phosphorus exists in stable chemical compounds, only a small amount of phosphorus is available to the plant at any given time. Fertilizer P is said to have a residual value that provides P for plants (and soil organisms) in the years after application (Bolland and Gilkes 1998). When P fertilizer applies to the soil it makes strong bounding with soil partials. This bound P release slowly in the year after application and act as residual P.

This research was conducted in order to address the following objectives-

- ✓ To investigate the effect of residual phosphorous (P applied to *aman*) on the seed yield of sunflower
- ✓ To examine the effect of current phosphorous application in combination with residual phosphorous on sunflower

- ✓ To suggest a P recommendation considering the response of residual P and current P application.

CHAPTER II

REVIEW OF LITERATURE

Sunflower is an important oilseed crop in many countries of the world. It is a short duration and photo-insensitive crop therefore it can be grown round the year provided there is no water stagnation. In Bangladesh sunflower is not grown commercially, although there is a great scope of growing this crop. Sunflower shows a great response to fertilizer applications. Literatures pertinent to this study, especially under Bangladesh condition, are not enough. However the author tried to present available review related to the present problem.

Effect of phosphorous on sunflower

Daniel *et al.* (2018) observed that the effect of phosphorous was significant in hastening physiological maturity of crop, and its effect was significant on flowering and growth parameters. The grain yield ranged between 2.43 t ha^{-1} at 0 kg phosphorous ha^{-1} and 2.67 t ha^{-1}at applications of 69 kg phosphorous ha^{-1}. Besides, total biomass was also significantly influenced by phosphorous and ranged between 4.4 t ha^{-1} at control to 4.87 t ha^{-1} at the rate of 69 kg P ha^{-1}. Both agronomic and physiological phosphorous use efficiencies of the crop were highest at the rate of 69 kg phosphorous ha^{-1}.

Ravishankar and Malligawad (2017) reported that plant height, stem girth, total dry matter production, head diameter, seed yield per plant, thousand seed weight, seed yield, oil content, oil yield and economics of sunflower was higher when P applied at 90 kg ha^{-1}.

Abubaker *et al.* (2014) revealed that phosphorus had no significant effects on head diameter, shelling percentage and 100-seed weight, but it had effect on days to 50%

flowering and chemical composition. Three P levels (0, 50 and 100 kg ha^{-1}) in the form of triple super phosphate were applied as experimental treatments.

Recently another research conducted in northern Ethiopia Hawzen district to investigate effect of phosphorus fertilizer level on the growth and yield of wheat also indicated phosphorus application at a rate of 46 kg P_2O_5 ha^{-1} increased significantly grain and straw yields by 38 % and 46 %, respectively than control (Bereket *et al.* 2014).

Shubhangi *et al.* (2014) conducted an experiment to study the effect of phosphorus and sulphur levels on soybean during 2009-10 and 2010-11.The treatment consisted of four levels of phosphorus (P0, P30, P60 and P90 kg P_2O_5 ha^{-1}) applied through DAP. Result indicated that grain and straw yield, uptake of phosphorus increased with increase in the rate of application of P. Applied various levels of P also influenced the quality parameters of soybean i.e. protein content and test weight. Available P in soil increased with increasing levels of phosphorus.

Ali and Noorka (2013) conducted an experiment to investigate the effect of phosphorus on sunflower hybrid Hysun-33 with three levels of phosphorus, viz., 50, 75, 85 kg P ha^{-1}. Results showed that phosphorus did not show significant effect on plant population and plant height. All other parameters, as leaf area plant-^{1}, head diameter, 1000- achene weight and achene yield were affected significantly by different phosphorus levels. The highest achene's yield (2584 kg ha^{-1}) was obtained with the application of 75 kg P ha^{-1} as against the lowest (1491kg ha^{-1}) at 50 kg P ha^{-1}.

Sadozai *et al.* (2013) showed significant effect of P_2O_5 @ 50 kg ha^{-1} and 60 kg ha^{-1} as compare to lower doses of phosphorous. All varying levels of phosphorous affected the head diameter, number of seeds per head, 1000-seeds weight, achene's yield and achene's oil content but significant positive effect was observed where P_2O_5@ 60 kg ha^{-1} N @ 50 kg ha^{-1} and K_2O 15 kg ha^{-1} was applied. However number of plants, remained non-significant. It is, therefore, recommended to apply phosphorous@ 60 kg ha^{-1} for obtaining higher yield of sunflower.

Abbadi and Gerendaas (2011) evaluated the phosphorus (P) requirement of sunflower in view of identifying low input oil crops. Sunflower responded strongly to increasing P supply with respect to plant growth and yield. Yield component analysis revealed that the major yield component influencing oil yield of sunflower was the number of achenes per plant. Contribution of the seed oil concentration to overall yield variation was insignificant.

Amanullah and Khan (2010) suggesting that the combined application of 100 kg K ha^{-1} and 45 kg P ha^{-1} significantly increased yield components, grain yield, harvest index, and shelling percentage of sunflower .

Application of 30 kg P ha^{-1} increased the grain yield and biomass yield of wheat by 6.5 t ha^{-1} (23.73%) and 11.27 t ha^{-1} (15.17%) respectively when compared with the no P application. The response to the increased application of P was associated with improvement in the concentration and uptakes of P and N that could account for the increase in yield. On the other hand, N and P uptakes by wheat ranged from 42.01 kg N ha^{-1} with no P to 52.28 kg N ha^{-1} at the rate of 30 kg P ha^{-1}, and 20.08 kg P ha^{-1} with no P to 29.06 kg P ha^{-1} at rate of 30 kg P ha^{-1}, respectively (Endalkachew, 2006).

Jahangir *et al.* (2006) observed that maximum number of seeds per head and yield were produced by the application of 75 kg P_2O_5 ha^{-1}.

Application of P fertilizer has positive relationship with yield and yield component of maize. According to Tilahun *et al.*(2006) research conducted on various sites of maize growing areas in north west Ethiopia revealed that application of phosphorous fertilizer significantly increases grain yield, plant height and thousand seeds weight and the highest grain yield (5242.8 kg ha^{-1})was obtained at the 138 kg ha^{-1} P_2O_5 rate.

Muralidharudu *et al.* (2003) found that soil available P status varies significantly only in low P status. They found critical P level in soil was to be 20 kg P ha^{-1}, below which sunflower may respond to phosphorus application.

Zubillaga *et al.* (2002) observed that to achieve a 100 % yield maximum N supply (soil plus fertilizer) of 181 kg N ha^{-1} at P40 was needed. However, at P0, the highest yield was about 80 % of the maximum yield with an N supply (soil plus fertilizer) of 164 kg N ha^{-1}. P application increased the apparent use efficiency of the supplied N.

Suzer (1998) observed that different level of phosphorous affect time to flowering, time to physiological maturity, plant height, head diameter, seed yield and 1000 seed weight, oil content, and oil yield. Relationship between sunflower grain yield and phosphorus rates was found significant it was recommended that the application rate of phosphorus should be 70 kg ha^{-1} in experimental condition.

Bahl *et al.* (1997) reported that significant yield response to N and P observed up to 60 kg N and 30 kg P_2O_5 ha^{-1}. Total N and P uptake also increased significantly with the applied nutrients. N application, in the absence of P, decreased oil percentage in sunflower seed. P application up to 30 kg P_2O_5 ha^{-1} resulted in significant increase in oil content.

Kumar *et al.* (1995) declared that in various P doses, 60 and 90 kg P ha^{-1} emerged to be the ideal as for as plant height is concerned. Turk *et al.* (2002) conveyed that almost all the growth and agronomic parameters were significantly affected by rate of phosphorous application in comparison to zero P.

Effect of residual phosphorous

The cowpea proved to be efficient in the use of residual phosphate fertilization, since it promoted grain yield close to the national average. The phosphorus dose applied in the predecessor crop corresponding to 80 kg·ha^{-1}of P_2O_5 promoted higher grain yield and a greater profit margin. Thus, it is feasible to grow cowpea in previously cultivated areas, in order to take advantage of residual phosphate fertilization (Gasper *et al.* 2018).

Amanullah and Inamlliah (2016) reported that in rice wheat cropping system, residual P of rice increase wheat grain yield significantly. Wheat was grown on the same layout of rice but no additional P was applied to wheat crop.

Rana *et al.* (2015) conducted an experiment to study the effect of phosphorus (P) on soybean-potato cropping system. Application of phosphorus along with biofertilizers to soybean had positive residual effect on the growth (vine length and leaf area index) of succeeding potato. Direct application of 100% of recommended dose of phosphorus (25.8 kg P ha^{-1}as Single Super Phosphate) to potato resulted in significantly higher tuber number and tuber yield, enhancing the yield up to 11.7% over control.

Sahrawat *et al.* (1997) conducted an experiment for three years (1993-1995) to determine the response of four upland rice cultivars to fertilizer P applied at 0, 45, 90, 145 and 180 kg ha^{-1} P only once in 1993, and to fertilizer P residues in 1994 and 1995. Result indicate that grain yield of the rice cultivars were significantly increased by fertilizer P in 1993, and by the fertilizer P residues in 1994 and 1995 although the magnitude of response decreased with time since the fertilizer was applied.

Mehedi and Datta (1996) revealed that there is a promising effect of residual P from the applied P sources in increasing rice grain yield. Total P uptake increased due to residual P from fertilizer P applied. Result suggested that increased P uptake increased dry matter and grain yield.

From the above literatures it is clear that, requirement of P fertilizer for sunflower is different for different location. Literatures also showed the residual value of P fertilizer. Under this observation present experiment was done to find the residual and current application effect of P fertilizer on sunflower and suggest a P dose for southwestern coastal soil, as there is no fertilizer recommendation for hybrid sunflower in this region.

mungbean and sesame but these are too risky harvest every year due to mid-season unwanted rainfall during march-April (Jahan *et al.* 2008).

3.2 Experimental details

3.2.1 Planting material

Hybrid sunflower seed of variety Hysun-33 was used in the experiment. Seed was collected from authorized dealer from Chuknagar, Khulna.

3.2.2 Treatment

To test the residual P on sunflower, P fertilizer was applied during T. *aman.* The recommended rate of P for T. *aman* for AEZ 13 is 10 kg ha^{-1} (FRG 2018). This rate was varied during T. *aman* (plot size was $40m^2$). In one half of a P treatment of T. *aman*, sunflower was grown without applying P fertilizer designated as RP treatments in the following Table of Factor A or applying current P fertilizer @ 50 kg ha^{-1} to investigate the effect of current P as Factor B. For sunflower, there is no fertilizer recommendation in the FRG (2018) for SW region but for other growing regions, there is a recommendation for an average yield of 2.0 ± 0.2 t ha^{-1} for the BARI released varieties, not for hybrid.

The treatments were designed as follows:

Factor A: Residual P (RP) – P applied during T. *aman* @, No P added in sunflower

RP_0 :	No phosphorous added in T. *aman*
RP_1 :	Residual of 5 kg P ha^{-1} applied in previous T. *aman*
RP_2 :	Residual of 7.5 kg P ha^{-1} applied in previous T. *aman*
RP_3 :	Residual of 10.0 kg P ha^{-1} applied in previous T. *aman*
RP_4 :	Residual of 12.5 kg P ha^{-1} applied in previous T. *aman*
RP_5 :	Residual of 15.0 kg P ha^{-1} applied in previous T. *aman*

Factor B: Current P

CP_0: No P added to sunflower

CP_1: 50 kg P ha^{-1} applied in sunflower

Other fertilizers such as nitrogen, potash, sulpher, zinc and boron were applied @ 120, 100, 30, 4, 2 kg ha^{-1} respectively.

The previous season *aman* plots were 40 sq m that was divided into two equal plots of (20 + 20) sq m in each replication. Half of the plots were treated as residual effect that means no phosphorous was added on that plots (Factor A). Only the plant could use the previous seasons phosphorous that was applied for *aman* rice. Rest half of the plots were treated with current phosphorous at the rate of 50 kg $ha^{-1}$and the residual phosphorous of *aman* rice was also present (Factor B).

3.2.3 Experimental design and layout

The experiment was laid out with factorial Randomized Complete Block Design (RCBD) with three replications. There were 36 unit plots and the size of the each unit plot was 4.0 m x 5 m (20 m^2). Plot to plot distance was 75 cm and block to block distance was 100 cm. Line to line distance was 70 cm and seeds to seed distance 40 cm.

The layout of the experiment is shown in appendix II.

3.3 Cultural operations

3.3.1 Land preparation

All weeds, stubbles and crop residues were removed and field layout was done on 27 December 2018. No tillage operation was done because the amount of moisture of soil was high (~40% v/v). But there was no standing water at the time of sowing.

3.3.2 Seed sowing

After harvesting of T. *aman,* sunflower seed was sown by dibbling under zero tillage condition when soil moisture (~40% v/v) was above the field capacity water. Previous T. *aman* was harvested at December 18, 2018 and sunflower was sown at December 28, 2018. After seed placement in the hole, seed holes were not covered with soil to facilitate oxygen supply to the seed in wet soil. Seedling emergence started after 4 days and completed within 7 days of dibbling.

3.3.3 Fertilizer application

Half of urea, total TSP, MoP, gypsum, zinc sulphate and boric acid were applied in both side (~5 cm) of a seed in two holes (5 cm deep) during sowing. Rest half urea was applied by side dressing after 30 DAS and then irrigation was given.

3.3.4 Thinning and weeding

After the establishment of seedling, keeping one healthy seedling the other seedlings were carefully uprooted by hand pulling. Weed infestation was low. Weeding was done twice, once at 30 DAS and the other on at 45 DAS.

3.3.5 Irrigation

Three irrigations were given, from the nearby canal by using pipe. The salinity of the canal water was ECw <3 dS/m.

3.3.6 Harvesting and threshing

When 80% of the plant leaves and dorsal side of the disc turned yellowish and central disc florets dried up and shed off on touch of fingers, the crop was assessed to attain maturity. The crop was harvested at the full maturity stage when most of the plants head started to droop and turn brown. Leaves were about to die. Harvesting was done manually. From each plot 7 randomly selected plants head was harvested. Harvesting was done 20 April 2019. The plants from each unit plot was harvested, bundled and tagged separately. Seeds were separated from the head and winnowed to remove trashes and inert materials. Seeds were sun dried before storing and then stored in a gunny bag.

3.4 Data collection:

Data were collected from randomly selected plants.

Growth characters

3.4.1 Plant height

The height of three randomly selected plants from net plot area were recorded at 30, 45, 60, 75, 90 DAP and at harvest. The height was measured in centimeters from the base of plant to the highest leaf tip with the help of meter rod. The average height of plants was calculated and expressed as plant height per plant.

3.4.2 Leaf number

The leaf numbers of three randomly selected plants from net plot area were counted at 30, 45, 60, 75, 90 DAP. The average number of leaf was calculated and expressed as leaf number per plant.

3.4.3 Plant biomass

One plant of 75 days age from each unit plots was cut down. These plants were first sun dried and then oven dried at 65 ^{o}C for three days. After drying, weight of each plant was calculated and average weight of plant biomass was expressed as g.

3.4.4 Days to first flowering and heading:

Flower initiation and heading dates were noted down by daily observation.

Yield attributes and yield:

3.4.5 Head diameter

The head diameter of seven randomly selected plants from net plot area was recorded. The diameter was measured in centimeters. The average diameter of heads was calculated and expressed as head diameter per plant.

3.4.6 Head circumference

The head circumference of seven randomly selected heads from net plot area was recorded. The circumference was measured in centimeters. The average circumference of heads was calculated and expressed as head circumference per plant.

3.4.7 Filled seed per head:

The number of filled seed per head was counted manually from seven sampled plants per plot then the average number of filled seed per head. was calculated.

3.4.8 Unfilled seed per head:

The number of unfilled seed per head was counted from seven sampled plants per plot then average value was calculated. All the seeds from all the seven sampled plants of each unit plot were counted to determine the average number of unfilled seed per head.

3.4.9 Number of seed per head:

The number of seed per head was counted from seven sampled plants per plot then average value was calculated. All the seeds from all the seven sampled plants of each unit plot were counted to determine the average number of seeds per head.

3.4.10 Seed weight per head:

The number of seed per head was counted from seven sampled plants per plot then average value was calculated. After that the yield of seven plants was adjusted to whole plot (as the number of plants per plot was constant because no plant was damaged for any reason).

3.4.11 1000 seed weight (g):

One thousand oven dry seed was counted from per plot and then weight was recorded by means of an electric balance.

3.4.12 Seed yield (t ha^{-1}):

Dry weight of seed from seven sampled plants of each plot was taken carefully, and then adjusted to whole plot and converted the seed weight into t ha^{-1}.

3.4.13 Stover yield (t ha^{-1}):

Per plot stover yield was measured and converted into per hector stover yield in ton.

3.4.14 Biological yield (t ha^{-1}):

Per plot biological yield was calculated by adding seed yield and stover yield and then it was converted into ton per hector.

3.4.15 Harvest index (%):

Harvest index (HI) is the ratio of economic yield (seed) to biological yield was estimated and expressed as percentage using the following formula:

$$\text{Harvest index (HI) (\%)} = \frac{\text{Seed yield}}{\text{Biological yield}} \text{ X } 100$$

Biological yield = Seed yield+ Stover yield

3.5 Data analysis:

Data on plant characteristics, yield and yield attributes were subjected to a two-way ANOVA following RCBD. All the recorded data were analyzed with the computer package Statistix 10 program. The significance of the difference among the treatment combinations means was estimated by the Duncan's New Multiple Range Test (DMRT) (Gomez and Gomez, 1984).

CHAPTER IV

RESULTS

Soil properties, weather condition and the results of the effect of residual and current P on sunflower are presented under the following subheads.

4.1. Soil properties

A composite soil sample (0-15 cm depth) was collected before the start of experiment. The soil sample was air dried ground and passed through 2 mm sieve and analyzed for different physico-chemical properties of soil. Soil of the experimental site was neutral in reaction (pH 7.3), medium salinity (EC 7.4), medium organic matter (OM 2.4 %), clay loam in texture, very low in available nitrogen (0.124 %), high in available phosphorus (31.34 μg/ g) and potassium (0.35 meq/100g), (Appendix I).

4.2. Weather condition

The upazila falls under tropical monsoon climatic condition like other parts of the country. The upazila has a hot summer and a mild winter. Here winter starts later and end earlier from the northern part of the country. The temperature and rainfall data were recorded at a nearby field weather station. Throughout the experiment (December 2018 to April 2019) the maximum temperature of December 2018, January 2019, February 2019, March 2019 and April 2019 was 29°C, 31.2°C, 33.5°C, 34.5°C and 37.2°C respectively and the minimum temperature was 8.0°C, 9.5°C, 11.4°C , 14.4°C and 19.8°C respectively (Figure 4.1). A heavy rainfall was held from 27 February (77mm) and 28 February (75mm) 2019 (Figure 4.2).

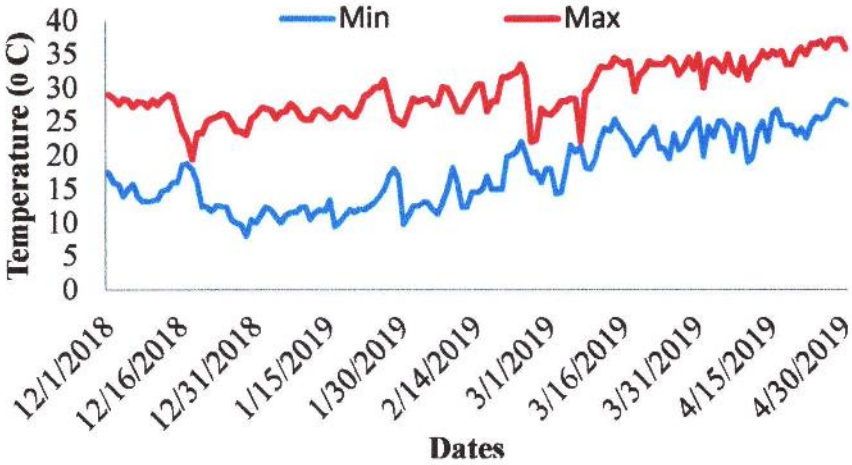

Figure 4.1: Maximum and minimum temperature during sunflower growing season (December 2018-April 2019) in the experimental field of Pankhali, Dacop, Khulna, Bangladesh

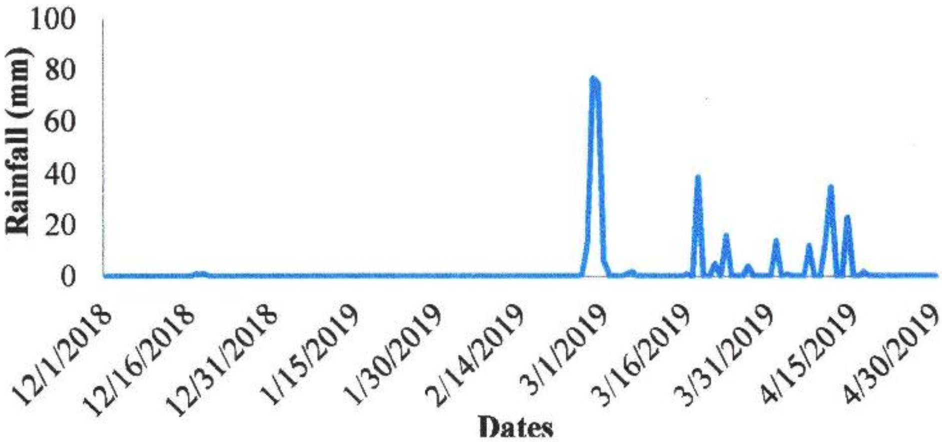

Figure 4.2: Rainfall during sunflower growing season (December 2018-April 2019) in the experimental field of Pankhali, Dacop, Khulna, Bangladesh

4.3 Water and soil salinity

The salinity level of the water at different sources was presented in figure 4.3. The salinity levels of the river water were gradually increased with the progress of dry season. The water salinity in the canal, pond and river are more or less similar but after the heavy rainfall at the last week of February the salinity level was decreased and then increase but not beyond the limit. In the experimental plot canal was used as the source of irrigation.

The canal was managed by disconnected it from the river during the middle of December. Soil salinity levels were presented in figure 4.4. The salinity level of soil increased with the progress of time. But it was decreased at the last week of February and then again increased but not beyond the limit. It might be due to the heavy rainfall at the last week of February 2019.

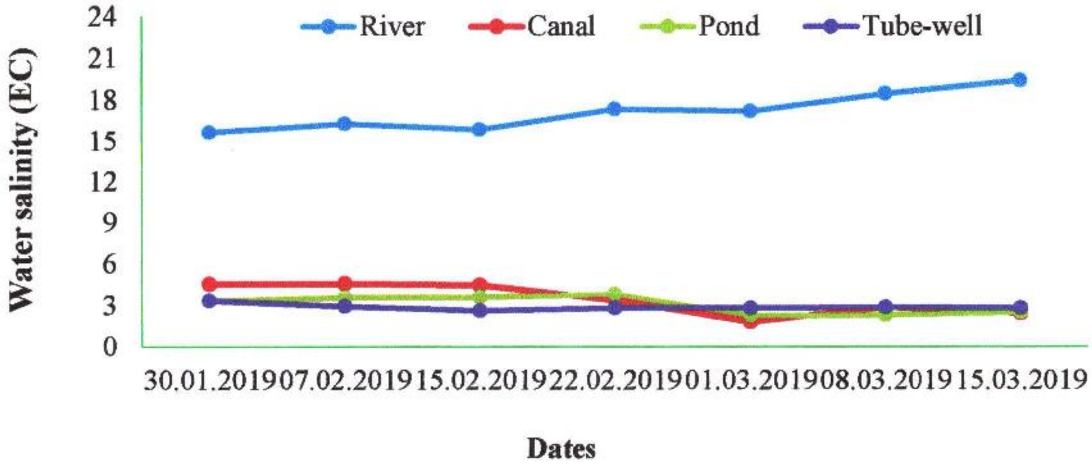

Figure 4.3: Water salinity at different sources of water with the progress of time during sunflower growing season (December 2018-April 2019)

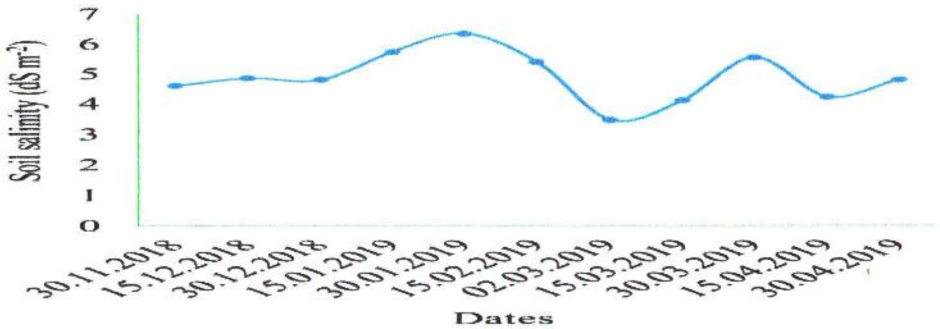

Figure 4.4: Soil salinity during experimental period (December 2018-April 2019) at the experimental site

4.4. Plant height

In residual P levels (P rates applied in previous T. *aman*) the plant height was non-significant (Table 4.1). Plants that were treated with current P @ 50 kg ha^{-1} resulted in significantly taller plants than zero added phosphorous at all dates of plant height measurement except 30 DAS (Table 4.2). The interaction of residual P and current P application was also non-significant thus the data was not presented.

Table 4.1: Effect of residual phosphorous on plant height of sunflower in a coastal soil of southwestern Bangladesh

Residual P	Plant height (cm)			
	30DAS	45DAS	60DAS	75DAS
RP_0 (no P added)	23.25	49.50	79.833	108.00
RP_1 (5.0 kg/ha)	22.38	49.50	78.333	108.67
RP_2 (7.5 kg/ha)	24.92	51.16	80.000	122.17
RP_3 (10.0 kg/ha)	22.96	50.83	77.000	110.17
RP_4 (12.5 kg/ha)	23.57	49.50	78.833	113.50
RP_5 (15.0 kg/ha)	26.71	53.66	81.167	121.67
LS	NS	NS	NS	NS
CV (%)	12.04	10.78	9.98	9.66

Table 4.2: Effect of current phosphorous on plant height of sunflower in a coastal soil of southwestern Bangladesh

Current P	Plant height (cm)			
	30DAS	45DAS	60DAS	75DAS
CP_0	23.19	48.05b	77.38b	109.94b
CP_1	24.74	53.33a	85.66a	118.11a
LS	NS	**	**	*
CV (%)	12.4	10.78	9.98	9.66

4.5 Leaf number

From treatments of residual phosphorous, leaf number of sunflower was significant at only 30 DAS and other parameters were non-significant (Table 4.3). Leaf number was significant at 45DAS and 60DAS for P application over no phosphorous added plants. Leaf number at 30DAS, 75DAS and 90 DAS showed non-significant effect in case of current phosphorous application (Table 4.4). Interactive effect of residual P (at 45 and 60 DAS) and current P (at 30 DAS) application was non-significant for the number of leaves of sunflower (Table 4.5).

Table 4.3: Effect of residual phosphorous on leaf number of sunflower in a coastal soil of southwestern Bangladesh

Residual P	Leaf number				
	30 DAS	45 DAS	60 DAS	75DAS	90 DAS
RP_0 (no P added)	10.50b	18.50	27.66	29.00	20.83
RP_1 (5.0 kg/ha)	10.667b	18.83	26.33	28.33	21.00
RP_2 (7.5 kg/ha)	11.50ab	19.66	28.00	30.33	20.50
RP_3 (10.0 kg/ha)	11.33ab	18.83	26.83	28.83	20.50
RP_4 (12.5 kg/ha)	10.83b	18.66	26.50	28.50	19.66
RP_5 (15.0 kg/ha)	12.33a	19.66	28.66	30.50	19.00
LS	*	NS	NS	NS	NS
CV (%)	8.85	6.13	6.71	6.63	8.02

Table 4.4: Effect of current phosphorous on leaf number of sunflower in a coastal soil of southwestern Bangladesh

Current P	Leaf number				
	30 DAS	45 DAS	60 DAS	75DAS	90 DAS
CP_0	10.94	18.38b	26.66b	28.72	20.33
CP_1	11.44	19.66a	28.00a	29.77	20.16
LS	NS	**	*	NS	NS
CV (%)	8.85	6.13	6.71	6.63	8.02

Table 4.5: Interaction of residual and current phosphorous application on leaf number of sunflowerin a coastal soil of southwestern Bangladesh

Residual P X current P	Leaf number		
	30 DAS	45 DAS	60 DAS
$RP_0 CP_0$	10.00	17.33	25.66
$RP_1 CP_0$	10.66	18.66	27.33
$RP_2 CP_0$	11.66	19.66	26.66
$RP_3 CP_0$	11.00	18.00	25.66
$RP_4 CP_0$	10.33	17.66	26.66
$RP_5 CP_0$	12.00	19.00	28.00
$RP_0 CP_1$	11.00	19.66	29.66
$RP_1 CP_1$	10.66	19.00	25.33
$RP_2 CP_1$	11.33	19.66	29.33
$RP_3 CP_1$	11.66	19.66	28.00
$RP_4 CP_1$	11.33	19.66	26.33
$RP_5 CP_1$	12.66	20.33	29.33

LS	NS	NS	NS
CV (%)	8.85	6.13	6.71

4.6 First heading and first flowering

The results showed that in plots with all levels of residual P, plants produced head and flower at statistically similar days (no significant difference) (Table 4.6). On the hand, early heading and flowering occurred in plant with current application of P (Table 4.7). Number of days to first heading and first flowering was reduced by phosphorus application at the rate of 50 kg P ha^{-1}. The data on the interactive effect of residual and current phosphorus on heading and flowering showed no significant effect (Table 4.8).

Table 4.6: Effect of residual phosphorous on first heading and first flowering of sunflower in a coastal soil of southwestern Bangladesh

Residual P	First heading (days)	First flowering (days)
RP_0 (no P added)	62.66	76.50
RP_1 (5.0 kg/ha)	62.66	76.66
RP_2 (7.5 kg/ha)	60.50	74.33
RP_3 (10.0 kg/ha)	61.66	76.00
RP_4 (12.5 kg/ha)	61.50	74.83
RP_5 (15.0 kg/ha)	62.33	73.33
LS	NS	NS
CV (%)	3.29	3.09

Table 4.7: Effect of current phosphorous on first heading and first flowering of sunflower in a coastal soil of southwestern Bangladesh

Current P	First heading (days)	First flowering (days)
CP_0	62.944a	77.833a
CP_1	60.833b	72.722b
LS	**	**
CV (%)	3.29	3.09

Table 4.8: Interaction of residual and current phosphorous application on first heading and first flowering of sunflower in a coastal soil of southwestern Bangladesh

Residual P X current P	First heading(days)	First flowering(days)
$RP_0\,CP_0$	64.33	80.00
$RP_1\,CP_0$	63.33	78.00
$RP_2\,CP_0$	61.66	76.33
$RP_3\,CP_0$	63.33	80.00
$RP_4\,CP_0$	61.33	77.00
$RP_5\,CP_0$	63.66	75.66
$RP_0\,CP_1$	61.00	73.00
$RP_1\,CP_1$	62.00	75.33
$RP_2\,CP_1$	59.33	72.33
$RP_3\,CP_1$	60.00	72.00
$RP_4\,CP_1$	61.66	72.66
$RP_5\,CP_1$	61.00	71.00
LS	NS	NS
CV (%)	3.29	3.09

4.7 Plant biomass

Residual phosphorous had no significant effect on plant biomass (Fig: 4.5). Plant biomass increased significantly with the application of current phosphorous in comparison to zero added phosphorous (Fig: 4.6). The interactive effect of residual and current phosphorous also had non-significant effect in case of plant biomass. (Fig: 4.7)

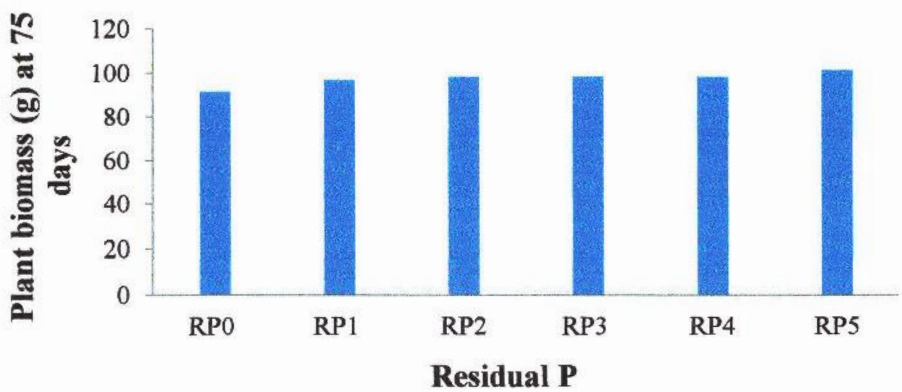

Figure 4.5: Effect of residual phosphorous on Plant biomass at 75 days of sunflower in coastal soil of southwestern Bangladesh

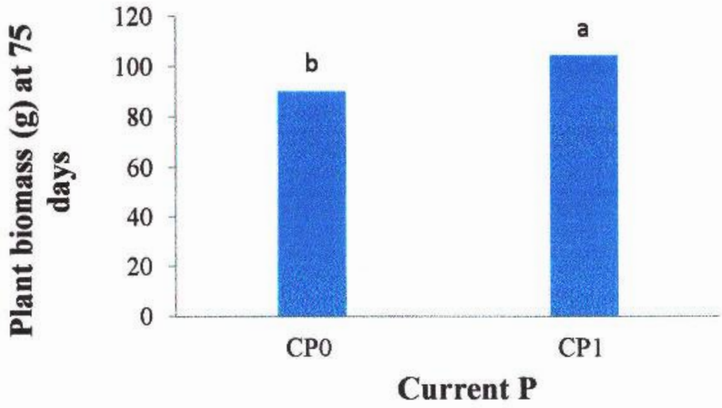

Figure 4.6: Effect of current phosphorous on plant biomass at 75 days of sunflower in coastal soil of southwestern Bangladesh

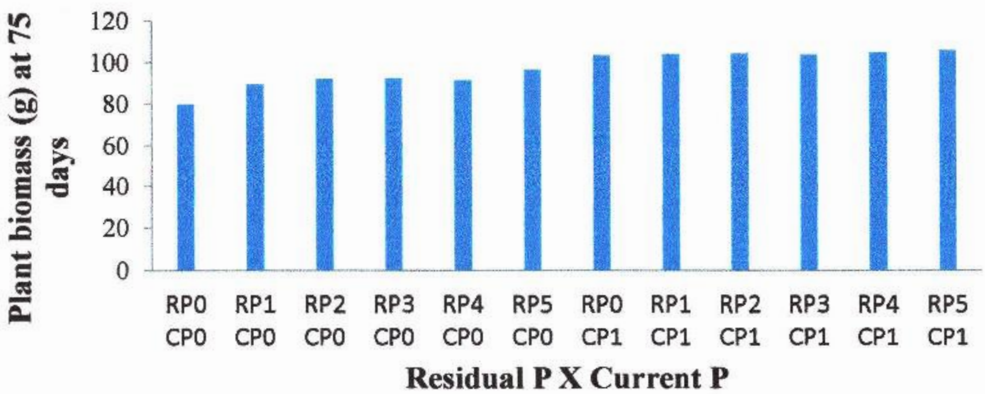

Figure 4.7: Interaction of residual and current phosphorous application of phosphorous on Plant biomass at 75 days of sunflower in coastal soil of southwestern Bangladesh

4.8 Yield attributes

In residual phosphorus (P) levels the head diameter, head circumference and seed head^{-1} was significant. The highest values in these parameters were obtained from residual P @ 15.0 kg ha^{-1} (applied in previous T. *aman*) which was statistically similar to all other residual P rates except no residual P treatment (Table 4.9). Statistically non-significant differences were recorded from residual phosphorus (P) on filled seed head^{-1} and unfilled seed head^{-1} (Table 4.9).

Results in Table 4.10 showed that, addition of phosphorous @ 50 kg ha^{-1} significantly increased the head diameter, seed $head^{-1}$ and less number of unfilled seed $head^{-1}$ in comparison to no addition of phosphorous. Statistically non-significant differences were recorded on head circumference, and filled seeds $head^{-1}$ in case of current phosphorous application (Table 4.10). The interactive effect of residual and current P in case of these yield attributes was insignificant (Table: 4.11)

Table 4.9: Effect of residual phosphorous on head diameter, head circumference filled seed $head^{-1}$, unfilled seed $head^{-1}$ and seed $head^{-1}$of sunflower in a coastal soil of southwestern Bangladesh

Residual P	Head diameter (cm)	Head circumference (cm)	Filled seed $head^{-1}$	Unfilled seed $head^{-1}$	Seed $head^{-1}$
RP_0 (no P added)	17.37b	17.04b	1022	62	1090b
RP_1 (5.0 kg/ha)	18.40ab	17.90ab	1112	62	1157ab
RP_2 (7.5 kg/ha)	18.78a	18.35a	1051	66	1183a
RP_3 (10.0 kg/ha)	18.85a	18.36a	1181	69	1207a
RP_4 (12.5 kg/ha)	18.93a	17.76ab	1138	65	1216a
RP_5 (15.0 kg/ha)	19.17a	18.63a	1239	57	1224a
LS	**	**	NS	NS	*
CV (%)	4.99	4.13	12.36	14.19	5.57

Table 4.10: Effect of current phosphorous on head diameter, head circumference filled seed $head^{-1}$, unfilled seed $head^{-1}$ and seed $head^{-1}$ of sunflower in a coastal soil of southwestern Bangladesh

Current P	Head diameter (cm)	Head circumference (cm)	Filled seed $head^{-1}$	Unfilled seed $head^{-1}$	Seed $head^{-1}$
CP_0	17.81b	17.921	1116	79a	1099b
CP_1	19.36a	18.100	1131	48b	1260a
LS	**	NS	NS	**	**
CV (%)	4.99	4.13	12.36	14.19	5.57

Table 4.11: Interaction effect of residual and current P application on head diameter, head circumference filled seed head^{-1}, unfilled seed head^{-1} and seed head^{-1} of sunflower in a coastal soil of southwestern Bangladesh

Residual P X Current P	Head diameter (cm)	Head circumference (cm)	Unfilled seed head^{-1}	See head^{-1}
$RP_0 CP_0$	15.70	16.72	79	969
$RP_1 CP_0$	17.50	17.50	81	1061
$RP_2 CP_0$	18.17	18.16	86	1107
$RP_3 CP_0$	18.27	18.03	85	1136
$RP_4 CP_0$	18.40	17.76	79	1154
$RP_5 CP_0$	18.83	19.33	65	1172
$RP_0 CP_1$	19.03	17.36	45	1211
$RP_1 CP_1$	19.30	18.30	43	1252
$RP_2 CP_1$	19.40	18.53	47	1259
$RP_3 CP_1$	19.43	18.70	53	1276
$RP_4 CP_1$	19.47	17.767	51	1278
$RP_5 CP_1$	19.50	17.933	48	1279
LS	NS	NS	NS	NS
CV (%)	4.99	4.13	14.19	5.57

At all levels of residual P, 1000 seed weight, and harvest index were increased significantly. The highest values in these parameters were obtained from residual P @ 15.0 kg ha^{-1} (applied in previous T. *aman*) which was statistically similar to all other residual P rates except no residual P treatment (Table 4.12).

The results in table 4.13 showed that current application of phosphorous increased the 1000 seed weight significantly in comparison to that of zero added P. On the other hand, current applied phosphorous had no significant effect on seed weight head^{-1}, stover yield and harvest index.

The interaction effect of current and residual phosphorous was found non-significant (Table 4.14).

Table 4.12: Effect of residual phosphorous on seed weight head^{-1}, 1000 seed weight, seed yield, stover yield and harvest index of sunflower in a coastal soil of southwestern Bangladesh

Residual P	Seed weight head^{-1} (g)	1000 seed wt. (g)	Stover yield (t ha^{-1})	Harvest Index (%)
RP_0 (no P added)	50.75	51.50b	2.74	40.14bc
RP_1 (5.0 kg/ha)	59.02	56.67a	2.94	41.77ab
RP_2 (7.5 kg/ha)	52.20	57.92a	3.18	36.93c
RP_3 (10.0 kg/ha)	60.09	58.58a	2.74	44.05a
RP_4 (12.5 kg/ha)	57.52	59.50a	3.08	40.52abc
RP_5 (15.0 kg/ha)	63.57	60.17a	3.02	43.41ab
LS	NS	*	NS	**
CV (%)	14.30	7.34	18.49	7.37

Table 4.13: Effect of current phosphorous on seed weight head^{-1}, 1000 seed weight, seed yield, stover yield and harvest index of sunflower in a coastal soil of southwestern Bangladesh

Current P	Seed weight head^{-1} (g)	1000 seed wt. (g)	Stover yield (t ha^{-1})	Harvest Index (%)
CP_0	55.54	53.75b	2.83	41.460
CP_1	58.84	61.03a	3.072	40.824
LS	NS	**	NS	NS
CV (%)	14.30	7.34	18.49	7.37

Table 4.14: Interaction effect of residual and current phosphorous application on 1000 seed weight, and harvest index of sunflower in a coastal soil of southwestern Bangladesh

Residual P X Current P	1000 seed wt. (g)	Harvest Index (%)
$RP_0 CP_0$	46.00	39.76
$RP_1 CP_0$	54.33	42.63
$RP_2 CP_0$	54.83	37.59
$RP_3 CP_0$	55.17	43.41

$RP_4 CP_0$	55.84	40.79
$RP_5 CP_0$	56.33	44.57
$RP_0 CP_1$	57.00	40.53
$RP_1 CP_1$	59.00	40.92
$RP_2 CP_1$	61.00	36.28
$RP_3 CP_1$	62.00	44.69
$RP_4 CP_1$	63.17	40.25
$RP_5 CP_1$	64.00	42.25
LS	NS	NS
CV (%)	7.34	7.37

4.9 Seed yield

Residual P had significant effect on seed yield of sunflower which was statistically similar to all other residual P rates except no residual P treatment (Fig: 4.8). Among the residual P levels, RP_3 and RP_5 produced 84% and 87% seed yield at 10 kg P ha^{-1} and 15 kg P ha^{-1} (applied in previous T. *aman*), respectively (Fig: 4.8). Current application of phosphorous also increased the final seed yield significantly in comparison to no addition of phosphorous. (Fig: 4.9). Current P produced ~0.4 t/ha more yields than that of zero added P. Interactive effect of residual P and current P application was non-significant for seed yield of sunflower (Fig: 4.10).

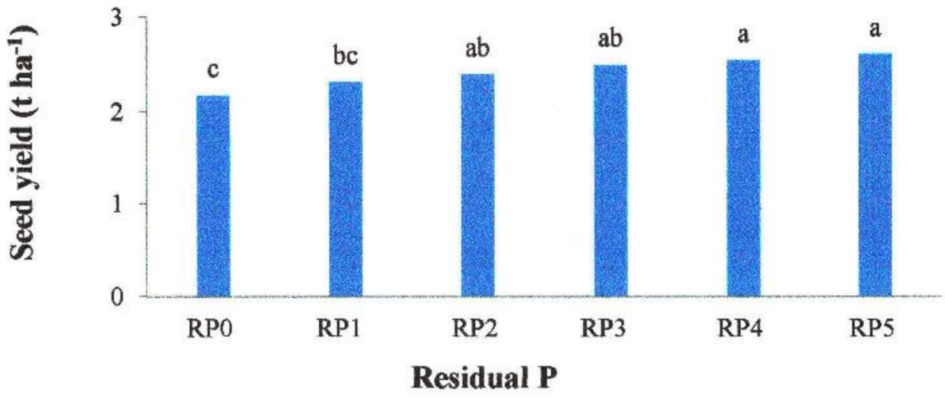

Figure 4.8: Effect of residual phosphorous on seed yield of sunflower in a coastal soil of southwestern Bangladesh

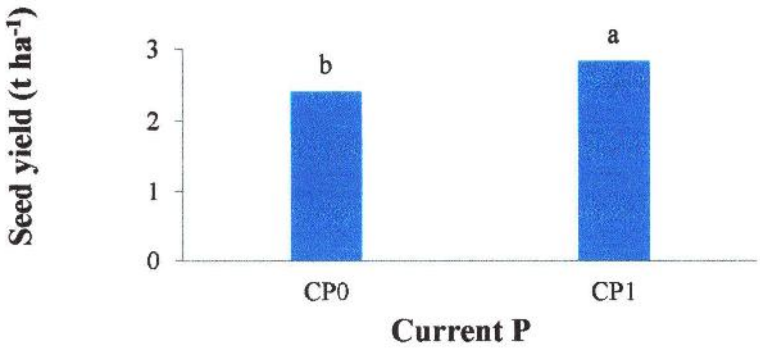

Figure 4.9: Effect of current phosphorous application on seed yield of sunflower in a coastal soil of southwestern Bangladesh

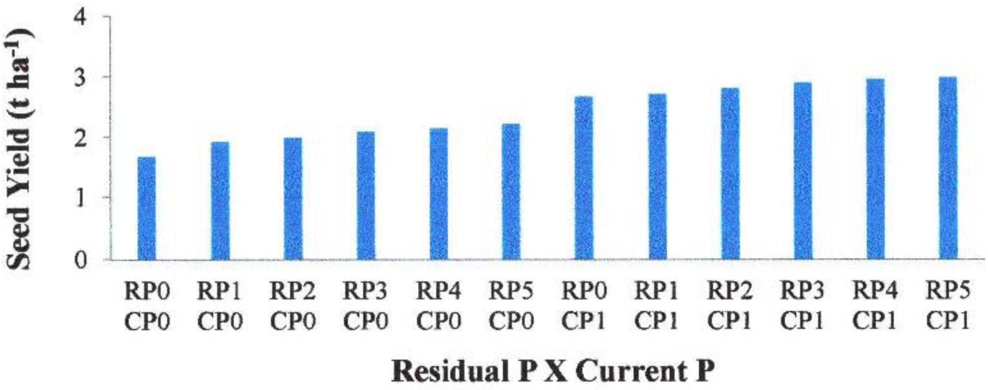

Figure 4.10: Interaction of residual P and current P on seed yield of sunflower in a coastal soil of southwestern Bangladesh

CHAPTER V

DISCUSSION

It is well known from numerous studies that yield of a crop strongly depends on the supply of nutrients (e.g., Laghan *et al.* 2016; Sezer *et. al.* 2012; Siddiqui *et. al.* 2009) and among the fertilizer nutrients, phosphorus is the second major nutrient after nitrogen in limiting the sunflower production (Aduayi *et al.* 2002). As phosphorus is more prone to fixation rendering it becomes unavailable to plants due to many soil reactions and interactions with other elements (Ryan *et al.* 1985). Consequently, a considerable portion of the fertilizers applied may remain in the soil as sorbed P in the forms of various P compounds, termed residual P (Bolland 1993; McPharlin *et al.* 1994).

In this study individually residual phosphorus had significant effect on sunflower seed yield (Fig. 4.8). The yield increase might be due to increase of some yield attributes (head diameter, head circumference, seed head^{-1} and 1000 seed weight) (Table 4.9 and Table 4.12). In RP_0 treatment (P was not applied to previous T. *aman* and sunflower) sunflower produced ~85% seed yield that of maximum produced at 100% recommended rate (RP_3 @10 kg P/ha) and 150% recommended rate (RP_5 @15 kg P/ha) that applied to previous T. *aman*. The yield in residual P treatment strongly suggests the presence of residual P fertilizer from previous T. *aman*. The soil P analysis before T. *aman* and after T. *aman* showed that the available P (Olsen P) of the field soil (0-15 cm) was high (30-35 μg/g soil) (FRG 2018) that might sufficient for the P requirement of sunflower. Eghball *et al.* (1990) reported that undisturbed, banded P fertilizer may remain available for 2.6–6.5 years, depending on the amount of applied P and the P adsorption characteristics of the soil. Aulakh *et al.* (2003) showed that residual P, in labile or moderately labile forms, was adequate to meet the needs of the second crop of groundnuts and increased fertilizer use efficiency compared to fertilizing both crops in the same year. In maize-mustard cropping system residual P significantly increased the seed and straw yields, nutrient uptake and the available N and P status of soil after mustard harvest (Mahala *et. al.*, 2006). Effect of residual P also found on some other crop such as rice, wheat, potato, cowpea etc (Sahrawat *et al.* 1997; Amanullah *et al.* 2016; Rana *et al.* 2015; Gasper *et al.* 2018).

P has strong bounding with soil constituents thus that plants could not utilize the current applied phosphorous fully. Only 10-30% of P applied as water-soluble P fertilizers is usually utilized by plants in the year of application. The P compound that are not taken up by plants in the year of application, return to the soil as organic matter and supply P into the soil in the years after application of the fertilizer (Bolland and Gilkes 1998). These diverse forms of residual P are utilized by plants in future years to different extents depending on solubility, microbial process and the external P requirement of the plant species (Bolland and Gilkes, 1990).

In this study current phosphorus application individually increased seed yield in comparison to zero added phosphorous. This result is supported by Mohamed *et al.*, (2003) who suggested that seed yield of sunflower was significant increased with an increasing level of P application. Such effects could be due to the impact of P on growth, dry matter production and yield components of sunflower. Agrawal *et al.* (2000) reported that seed and straw yields were increased up to the highest rate of P. Turk *et al.* (2002) also found that high rates of phosphorus increased seed yield significantly.

The yield gap between zero added P and current P was only 0.4 t ha^{-1} (Fig: 4.9). Plants that were treated with phosphorous @ 50 kg ha^{-1} produced seed yield of 2.84 t ha^{-1}.On the other hand plants that were treated with no phosphorous (P was not added in sunflower) produced seed yield of 2.41 t ha^{-1}. By applying 50 kg ha^{-1} phosphorus fertilizer only 15% yield was increased in comparison to yield from residual P (Fig: 4.9). If the cost of 50 kg phosphorus fertilizer and its application (by dibbling, not broadcasting) cost are considered then it might help to take the decision of applying or not applying P fertilizer to sunflower.

Table 5.1: Yield difference between current P and residual P treatment, price of that yield and fertilizer application cost in a coastal soil of southwestern Bangladesh

P fertilizer	Yield ($t\ ha^{-1}$)	Yield difference ($kg\ ha^{-1}$) (seed price in Tk @ 30 Tk kg^{-1})			Cost (Tk) of 50 kg P fertilizer @ 23 Tk kg^{-1}	Fertilizer application Cost (Tk) (400 Tk $labour^{-1}$) (22 labour ha^{-1} approximately)	Total cost (Tk ha^{-1}) for adding fertilizer
		CP_1 minus RP_0	CP_1 minus RP_3	CP_1 minus RP_5			
CP_1	2.84	660 (19800)	340 (10200)	230 (6900)	1150	8800	9950
RP_0	2.18						
RP_3	2.50						
RP_5	2.61						

Table 5.1 showed that yield difference between CP_1 and RP_0 was 660 kg ha^{-1}.To increase this 660 kg yield in RP_0, 50 kg ha^{-1} P fertilizer would be required and the labor cost for fertilizer application is 9950 Tk ha^{-1} while the price of 660 kg seed is 19800 Tk. If fertilizer cost is considered then the benefit will be 9850 Tk (excluding all other cost because other cost for each treatment is similar). On the other hand if we compare yield difference between CP_1 and RP_3 (100% recommended rate of P 10 kg ha^{-1} for T. *aman*), CP_1 produced 340 kg more yield than RP_3 whose price was 10200 Tk. Again comparison between CP_1 and RP_5 (150% recommended rate of P 15 kg ha^{-1} for T. *aman*), showed that CP_1 produced 230 kg more yield than RP_5 and its price was 6900 Tk (Table 5.1).If the fertilizer cost (9950 Tk) is considered then there is no need to apply current P fertilizer in sunflower. This indicate that residual phosphorous present in soil was adequate for the

production of maximum seed yield of sunflower. Although current P did produce more seed yield than residual P, considering the fertilizer price and application cost, residual P from t. *aman* rice seems provide small or marginal return.

From the above discussion it is clear that, residual phosphorous from previous *aman* season is more or less sufficient for the production of sunflower. Seed yield of 84% and 87% was obtained from 100% (10 kg P/ha) and 150% (15 kg P/ha) recommended rate of T. *aman* respectively. If farmers want to produce 100% yield of sunflower, they can apply P fertilizer, less than 50 ka P ha^{-1} (it may be 20-25 kg P ha^{-1}) in presence of residual P. Further study should conduct by applying P fertilizer less than 50 kg ha^{-1}. Investigation may also be done by broadcasting small amount of P fertilizer (e.g., 10, 20, 30 kg P ha^{-1}) in the wet soil just before rice harvest to avoid fertilizer dibbling cost. Finally the study revealed that recommended P rate for T. *aman* can produce 85% seed yield compared to current application of P to sunflower. This yield might contribute to add a second crop in the fallow land that will increase the cropping intensity of these fallow areas.

CHAPTER VI

SUMMARY AND CONCLUSION

The experiment was conducted in the farmer's field at Pankhali village, Dacope, Khulna, Bangladesh during December 2018 to April 2019 to find out the effect of residual and current phosphorous on sunflower in wet soil of southwestern Bangladesh. The main constrain of *rabi* crop production in southwestern costal soil is excess water remain in the soil after T. *aman* and during the optimum sowing time of winter crop. So after T. *aman* harvest, without any tillage operation sunflower seed was sown by dribbling. The experiment was designed in factorial RCBD, Factor A: Residual P (RP) – P applied during T. *aman* @ six different rates (0, 5, 7.5, 10, 12.5 and 15 kg P ha^{-1}), No P added in sunflower and Factor B: Current P. The results showed that yield and yield attributes varied significantly among the treatments. However, numerically highest seed yield was recorded at current applied phosphorous (2.84) than residual phosphorous (2.41) treatment. But yield gap between current P and residual P was not high. By applying phosphorous fertilizer @ 50 kg ha^{-1}, sunflower produced only 15% more seed yield than residual phosphorous from previous T. *aman*. The total cost of 50 kg ha^{-1} phosphorous fertilizer and application cost was 9950 Tk ha^{-1}. Considering the fertilizer cost, residual phosphorous was adequate for the production of remunerative seed yield of sunflower. By cultivating sunflower, in the fallow land using the residual phosphorous fertilizer the cropping intensity can be increased and the livelihood of the farmers can be increased.

The study arrived at conclusion that sunflower production in the southwestern coastal soil could be profitable by using residual phosphorous from previous T. *aman*. Current application of phosphorous fertilizer in presence of residual P also help increase seed yield but in small amount. Considering the response of residual P and current P farmers may apply much less amount of current P (<50 kg P ha^{-1}) to produce sunflower seed yields but need further research to determine that rate.

For this assumption, trial should be done on varying current P rates for sunflower keeping in mind that the soil has sufficient residual P. Further research is required to determine whether residual P will consistently support seed yield of sunflower. This would discourage excessive mineral fertilizer application which may reduce the cost of sunflower cultivation and encourage the farmers to get a second crop after T. *aman* otherwise the land would remain fallow.

CHAPTER VII

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APPENDIX

Appendix I: Chemical properties of the soil (experimental plot soil) of Pankhali, Dacope, Khulna, Bangladesh

Soil properties	Values	Condition
pH	7.3	Neutral
EC	7.4	Medium
OM (%)	2.4	Medium
N (%)	0.124	Low
P (µg/ g)	31.34	High
K (meq/100g)	0.35	High
Cu (µg/g)	107.42	Very high
Zn (µg/g)	1.51	High
B (µg/g)	1.16	Very high

Appendix II: Layout of the experimental field (sunflower) of Pankhali, Dacope, Khulna, Bangladesh (Shown as non randomize)

Rep I			Rep II			Rep III	
RP	CP		RP	CP		RP	CP
0 kg/ha	50 kg/ha		0 kg/ha	50 kg/ha		0 kg/ha	50 kg/ha
5 kg/ha	50 kg/ha		5 kg/ha	50 kg/ha		5 kg/ha	50 kg/ha
7.5 ka/ha	50 kg/ha	↔ 1m	7.5 kg/ha	50 kg/ha	↔ 1m	7.5 kg/ha	50 kg/ha
10 kg/ha	50 kg/ha		10 kg/ha	50 kg/ha		10 kg/ha	50 kg/ha
12.5 kg/ha	50 kg/ha		12.5 kg/ha	50 kg/ha		12.5 kg/ha	50 kg/ha
15 kg/ha	50 kg/ha		15 kg/ha	50 kg/ha		15 kg/ha	50 kg/ha

(RP= Residual P, from previous T.*aman* and CP= Current P)

Appendix III: Layout of T. *aman* field of Pankhali, Dacope, Khulna, Bangladesh (Shown as non-randomizep)

Rep I	Rep II	Rep III
0 kg/ha	0 kg/ha	0 kg/ha
5 kg/ha	5 kg/ha	5 kg/ha
7.5 kg/ha	7.5 kg/ha	7.5 kg/ha
10 kg/ha	10 kg/ha	10 kg/ha
12.5 kg/ha	12.5 kg/ha	12.5 kg/ha
15 kg/ha	15 kg/ha	15 kg/ha