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Residual Effects of Applied Chemical Fertilisers on Growth and Seed Yields of Sunflower (*Helianthus annuus* cv. High Sun 33) After the Harvests of Initial Main Crops of Maize (*Zea mays* L.), Soybean (*Glycine max* L.) and Sunflower (*Helianthus annuus*)

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Abstract: The experiments consisted of two locations, i.e., the first one was carried out on a growers's upland area at Saraburi Province, Central Plane region of Thailand with the use of Chatturat soil series (Typic Haplustalfs, fine, mixed) and the second experiment was carried out at Suranaree Technology university Experimental Farm, Suranaree Technology University Northeast Thailand with the use of Korat soil series (Oxic Paleustults). The experiments aimed to investigate the effect of residual effects of applied chemical fertilisers on growth and seed yields of sunflower (*Helianthus annuus*) after the harvests of initial main crops of maize, soybean and sunflower. The experiments consisted of four cultural methods being practiced by growers in both regions. For Methods 1 and 2, each had four fertiliser treatments; Method 3 consisted of two fertiliser treatments and Method 4 was used as a control treatment. The results showed that soil pH, organic matter and nutrients of Korat soil series were most suited soil conditions for growth of sunflower plants, whilst that of Chatturat soil series at Saraburi province was an alkaline soil with a mean value of soil pH of 7.8. Chatturat soil series, in most cases, gave higher amounts of seed yields (1,943.75 kg ha^{-1}) than Korat soil series. Residual effects of applied chemical fertilisers to main crops of soybean gave better growth and seed yields of sunflower plants and it is considered to be the first choice. The use of sunflower and maize as main crops gave a second choice for subsequent crop of sunflower.

Key words: Chemical fertilisers, residual effects, maize, seed yields, sunflower, soybean, soil conditions

INTRODUCTION

Thailand is one of many tropical countries, in which many agricultural crops have been produced for both domestic and overseas consumption such as rice (*Oryza stiva*), cassava (*Manihot esculenta* Crantz), sugarcane (*Saccharum officinarum*) and many others (Suksri, 1999). The cultivation of many important crops in Thailand e.g., rice, maize, sunflower and soybean as main crops has been orientated from generation to generation. The cultivation of the ancient time was mostly carried out under cultural practices where scientific cropping systems were not vividly applied. However, within the past few decades, scientific cropping systems have been introduced to growers of most regions of the country, particularly in northeastern region where a large amount of aromatic rice has been produced and exported overseas apart from domestic consumption (Anonymous, 1976). One of many problems in crop cultivation in the tropics is the rapid deterioration of soil fertility due to many environmental factors, e.g., soil erosion, leaching and the previous cultivation without soil fertility programme (Suksri *et al*., 1991). Furthermore, many soil series contained a large amount of sandy particles with poor percentages of soil organic matter, thus some large amounts of soil nutrients could have been taken away in such manners (Suksri, 1999; Pholsen, 2003; Kasikranan, 2003).

The practice in growing one crop after the other crops within a certain period of the season such as sunflower (*Helianthus annuus*) is grown after soybean (*Glycine max*) or maize (*Zea mays* L.) has been proven to produce maximum outputs of the cultivated land (Mernegay, 1976). Crabtree and Rupp (1980) showed that the cultivation of wheat (*Triticum aestivum*) after soybean within the same season gave total crop yields higher than growing only a single crop alone. The practice aided the subsequent crop plants to utilise nutrients more efficiently since soybean plants of the first crop may have produced some certain amounts of root nodules apart from crop residues of the soybean plants. Growers of many crops in different provinces in Thailand, particularly in the Central Plane region have obviously planned to grow their crops with different cropping patterns. Anonymous (2002) showed that with a total number of 79 growers, 45 grown sunflower after the harvest of maize, 32 grown sunflower after the harvest of a cereal crop of Mung bean (*Phaseolus aureus*) and the last one left the land without any subsequent crop. In each growing season, growers of sunflower plants normally grow sunflower as a second crop without any fertiliser added to the soil after the harvest of their initial main crop. Thus this investigation has its impact on how the sunflower plants responded to nutrients left in soils after the initial main crop has been harvested. This study aimed to justify growth and yield of sunflower when grown after maize, soybean and sunflower as initial main crops. This could possibly be one way in finding out residual effect of chemical fertilisers left in soils after the harvest of initial main crops, since most of the tropical soils obviously possess inadequate amounts of soil nutrients due to high leaching rate and soil erosion apart from being taken away by the crops during the growing session as mentioned earlier. In Thailand, sunflower crop has recently been considered as one of many important cash crops for growers to cultivate due to its high oil content in seeds and a by-product of seed meal after the extraction of oil from seeds where this by-product can be used as an essential material in processing animal feed such as poultry, dairy, beef and others (Suksri, 1996). The attained results may be of tangible value to growers of sunflower crop in most regions of the country, particularly the Central Plain areas where a large amount of sunflower seeds has been annually produced for mostly edible cooking oil.

MATERIALS AND METHODS

This investigation consisted of two experiments of two locations. The first experiment of the first location was carried out on a farmer's land at Saraburi province (Central Plane region) with the use of Chatturat soil series (Typic Haplustalfs, fine, mixed) during June 1999 to January 2000. The second experiment of the second location was carried out at the Experimental Farm, Suranaree Technology University (Northeastern region) with the use of Korat soil series (Oxic Paleustults) during February to September 2000. Soil analysis data of Korat soil series being analysed for mean values of soil pH, soil organic matter, soil available phosphorus, soil exchangeable potassium, calcium and magnesium were 6.00, 3.2%, 29, 300, 2400 and 1160 ppm, respectively. For Chatturat soil series, soil analysis was carried out only with soil pH and organic matter with mean values of 7.8 and 1.72%, respectively. The experimental design used was a group-balanced block with four replications where maize and soybean were used as main initial groups. There were four chemical fertilisers application methods used i.e. Method 1 was used for maize experiment. This experiment had 4 treatments (T_1-T_4) of 4 rates of chemical fertilisers, i.e., T_1 = 0 kg ha^{-1} (control), T_2 = 125 kg ha^{-1} of 15-15-15 (NPK), T_3 = 125 kg ha^{-1} of chemical fertiliser 15-15-15 (NPK) plus rock phosphate at a rate of 625 kg ha^{-1} and T_4 = 250 kg ha^{-1} of 15-15-15 (NPK). Method 2 was used for soybean experiment. This method had 4 rates of chemical fertilisers, i.e., T_1 = 0 kg ha^{-1} (control), T_2 = Urea (46-0-0, NPK) at a rate of 100 kg ha^{-1}, T_3 = Urea at a rate of 100 kg ha^{-1} plus 625 kg ha^{-1} of rock phosphate and T_4 = 206.25 kg ha^{-1} of chemical fertiliser 12-24-12 (NPK). Method 3 was used for sunflower experiment. This method had 2 treatments of 2 rates of chemical fertiliser, i.e., T_1 = 0 kg ha^{-1} (control), T_2 = Chemical fertiliser 15-15-15 (NPK) at a rate of 250 kg ha^{-1}. Method 4, with this method the land area was not in used, i.e., without initial crop but soon after the harvests of the initial crops of the first three methods then sunflower seeds were drilled into the soil at the same time as those of the plots of the three methods. The sowing distance used was a 70×30 cm between rows and within rows, respectively. This sowing distance was used in all experiments for both maize and sunflower. The sowing distance used for soybean was a 70×20 cm between rows and within rows, respectively. The plot dimension used was a 4.2×10 m for both maize and sunflower and a 3.0×10 m for soybean.

The land areas of both locations were ploughed twice followed by harrowing once (excluded Method 4). Seeds of maize, soybean and sunflower were sown by hand directly into the soil to the depth of approximately 7-15 cm. Before sowing, a pack of *Bradyrhizobium japonicum* rhizobium was thoroughly mixed with soybean seeds and then the seeds were sown directly into the soil by hand. After the sowing of seeds of the three crops one half of each rate of chemical fertiliser treatments were evenly applied to their respective plots and treatments where appropriate and the other half was applied at 30 days after emergence. One week after germination, seedlings were thinned out leaving only one seedling hole^{-1} for both maize and sunflower but two seedlings hole^{-1} for soybean. It may be generalized that the four methods in sowing seeds of the three crops are normally practiced by growers in most regions of the country (cf. Department of Agricultural Extension, Ministry of Agriculture and Cooperatives, Bangkok, Thailand).

Weeding was carried out by hand once at 30 days after emergence and then weeding was no longer needed when the crop plants had grown up with a large amount of dense leaves covered the ground area. The harvests for seed yields of the three crops were carried out soon after they reached physiological maturity. Seeds of the three crops were taken out, whilst stems and leaves of the three crops were chopped into small pieces and evenly spread out to cover their respective plots. Before the spread out of the crop residues, weeding was carried out by hand where the weed plant materials were also chopped into small pieces and returned to their respective plots.

Sunflower seeds of Hysun 33 obtained from Thailand Pacific Seeds Com. Ltd., were drilled by hand into the soil in each plot where no tillage was applied to the plots. The sowing distance between rows and within rows used was a 70×30 cm, respectively. Five to seven days after emergence seedlings were thinned out leaving only one seedling hole^{-1}. Weeding was carried out once in all plots at 30 days after emergence. The following sampling parameters were carried out only for the experiments done at the farmer's land at Saraburi province, they include plant height, diameter of capitula, 1000-seed weights and seed yields ha^{-1}. The experiment carried out at Suranaree Experimental Farm had only the data on plant height, capitulum diameter and seed yields ha^{-1}. The results obtained from both locations were statistically analysed where appropriate using an MSTAT-C computer programme (Nissen, 1989).

RESULTS

Plant height, capitulum diameter, 1000-seed weight and seed yields with the results obtained from a farmer's land at Sraburi province, in most cases, plant heights with fertiliser treated treatments were higher than control treatments of the four cultivated methods except treatments of Methods 2 (soybean) and 4 (sunflower) where control treatments of both treatments gave a similar significant level as those of the fertiliser treated plants with mean values ranged from 105 to 152 cm for T_1 (method 1, maize) and T_4 (method 2, soybean), respectively (Table 1). Control treatments of maize (method 1) and sunflower (method 3) gave lower plant heights than control treatments of soybean (method 2) and without crop (method 4). The differences were large and statistically significant. With capitulum diameter, the results showed that capitulum diameters were slightly greater for those of method 2 than the rest but statistical differences among the treatments were not found except that of T_1 (method 1, maize) and treatment without crop (method 4) where their mean values were significantly lower than the rest with mean values ranged from 8.19 to 10.47 cm for T_1 (method 1) and T_2 (method 2), respectively. In most cases, capitulum diameters of the fertiliser treated plants were not different from one another.

For 1000-seed weights, the results showed that 1000-seed weights of the fertiliser treated plants of methods 1 and 2 were similar and the lowest was found with T_1 (method 1), T_1 (method 3) and a treatment without crop (method 4) with mean values ranged from 48 to 58.60 cm for T_1 (method 1) and T_4 (method 1), respectively. Control treatment of method 2 (soybean) gave a similar 1000-seed weight as that of method 4 (without crop) but was not different from control treatments of the four methods. Seed yields ha^{-1}, in most cases, were similar for the fertiliser treated plants but greater than control treatment of method 1 and also a treatment of method 4 (without crop) with mean values ranged from 943.75 to 1, 943.75 kg ha^{-1} for T_1 (method 1) and T_4 (method 2), respectively. T_1 (control) of method 2 gave a similar seed yield to all fertiliser treated plants with mean seed yield of 1,825.00 kg ha^{-1}.

With the results obtained from the experiment carried out at Suranaree Technology University Experimental Farm, the results showed that plant heights, in most cases, were highest with those fertiliser treated plants and also with a treatment without crop (method 4) with mean values ranged from 107.00 to 152.00 cm for T_1 (method 1) and T_4 (method 2), respectively. The differences were large and statistically significant (Table 2). For capitulum diameters, the results showed that capitulum diameters did not increase with an increase in fertiliser levels in all methods used. However, in most cases, the fertiliser treated plants gave higher mean values of capitulum diameters than control treatments of T_1 (method 1), T_1

Table 1: Mean values of plant height, capitulum diameter, 1000-seed weight and seed yield of sunflower Hysun 33 cultivar as affected by different chemical fertilisers application methods grown on Chatturat soil series, Saraburi province, Thailand

Initial crops	Treat-ments	Plant height (cm)	Capitulum diameter (cm)	1000-seed weight (g)	Seed yields (kg ha^{-1})
Maize (Method 1)	T_1	105c	8.19c	48.00c	943.75c
	T_2	129ab	9.30bc	56.10b	1,675.00ab
	T_3	124abc	9.55bc	58.40b	1,968.75a
	T_4	132ab	9.94b	58.60b	1,743.75ab
Soybean (Method 2)	T_1	128ab	9.04bc	54.90bc	1,825.00ab
	T_2	144a	10.47b	57.70b	1,850.00ab
	T_3	150a	10.20b	58.70b	1,893.75ab
	T_4	152a	9.84b	58.30b	1,943.75ab
Sunflower (Method 3)	T_1	113bc	9.17bc	53.2bc	1,575.00abc
	T_2	128ab	9.55bc	57.10b	1,893.75ab
Without crop (Method 4)		136a	8.34c	50.20bc	1,350.00bc

Letter(s) in each column indicate significant differences of Duncan's Multiple Range Test (DMRT) at probability (p) of 0.05

Table 2: Mean values of plant height, capitulum diameter, 1000-seed weight and seed yield of sunflower Hysun 33 as affected by different chemical fertilisers application methods grown on Korat soil series (Oxic Paleustults) at Nakhon Ratchasima province, Thailand

Initial crops	Treatments	Plant height (cm)	Capitulum diameter (cm)	Seed yields (kg ha^{-1})
Maize (Method 1)	T_1	107.00d	6.61cd	1,268.75c
	T_2	146.00ab	7.64ab	1,518.75b
	T_3	114.00cd	6.83bcd	1,768.75a
	T_4	143.00ab	6.40d	1,825.00a
Soybean (Method 2)	T_1	127.00bc	6.09d	1,306.25c
	T_2	145.00ab	6.63bcd	1,493.75bc
	T_3	150.00a	7.53abc	1,568.75b
	T_4	152.00a	6.55cd	1,543.75b
Sunflower (Method 3)	T_1	112.00cd	7.54abc	1,431.25bc
	T_2	129.00bc	7.87a	1,581.25b
Without crop (Method 4)		136.00ab	6.80bcd	1,325.00c

Letter(s) in each column indicate significant differences of Duncan's Multiple Range Test (DMRT) at probability (p) of 0.05

(method 2) and a treatment without crop (method 4) with mean values ranged from 6.61 to 7.87 cm for T_1 (method 1) and T_2 (method 3), respectively. Similarly, seed yields ha^{-1} of the fertiliser treated plants, in most cases, significantly higher than those of the control treatments (T_1, method 1; T_1, method 2) but similar to T_1 (method 3) and a treatment without crop (method 4) with mean values ranged from 1,268.75 to 1,825.00 kg ha^{-1} for T_1 and T_4 (method 1), respectively. There were no trends on seed yields due to fertiliser levels found.

DISCUSSION

Soil analysis data of Korat soil series (Oxic Paleustults) at Suranaree Technology University Experimental Farm indicated an ideal soil type for crop growth where it presumably provides, more or less an adequate amount of soil macronutrients and in particular it provides high percentages of organic matter where the mean value reaches a value of 3.2%. The results suggested that the high percentage of organic matter could possibly have been due to some enormous amounts of plant residues previously added to the soil and this high value of organic matter could have been acted as a nutrient reservoir for plant roots to absorb (Miller and Donahue, 1990). Ratnapradipa (1996) and Suksri (1999) reported that tropical soils normally contain less than 1% of organic matter due to a rapid decomposition rate of microbial activity as a result of high environmental temperatures. Thus this Korat soil series may need only a small amount of chemical fertilisers to be added to the soil when available soil phosphorus (P) exceeded 20 ppm and at the same time exchangeable potassium (K) exceeded 80 ppm. These levels of both P and K could be considered to be an optimal amount for normal growth of most crop plants (Miller and Donahue, 1990; Suksri, 1999). Furthermore, soil pH of 6 (1:1 soil: water by volume) may be considered to be an ideal soil pH for growth when adequate amounts of nutrients could be adequately released (Mengel and Kirkby, 1987). With Chatturat soil series at Saraburi site, soil pH was relatively high reaching a mean value of 7.8 (1:1 soil: water). The result indicated that the soil of this type must have contained some large amounts of calcium cation (Ca^{2+}). Mengel and Kirkby (1987) stated that in organic soils, in particular, the pH should not be too high since they are obviously poor in a number of plant nutrients and the release is generally suppressed by high pH conditions. High value of soil pH also influences the occurrence and activity of soil microorganisms. Thus Chatturat soil series may need some large amounts of organic materials to be added to the soil annually in order to provide adequate amounts of soil nutrients for most cash crops (Suksri, 1999).

With maize treatments (Method 1) carried out at Saraburi farmer's land, the results showed that all of fertiliser treated plants (T_2-T_4), in most cases, gave significantly higher plant heights and capitulum diameters than the control treatment. The results indicated that soil type of maize plots needs an annual chemical fertiliser application in order to achieve sustainable agriculture. The results on 1000-seed weight and seed yields of sunflower plants treated with chemical fertiliser were significantly higher than control treatments (T_1, method 1 and T_1, method 3) and also a treatment without crop (method 4). The results indicated that residual amounts of fertiliser left in soil of T_3 and T_4 were adequately available. Thus the practice in growing sunflower after maize of growers in the region could possibly be acceptable. With soybean experiment (method 2), all fertiliser treated plots, in most cases, gave a slightly higher seed yields than those plots of maize. The results suggested that the soybean plants (used as main crop) may have contributed some certain amounts of nitrogen to the soil by producing root nodules where T_1 (control) gave a similar seed yield to other fertiliser treated plants, thus sunflower plants of the control treatment were able to attain high seed yield similar to other fertiliser treated plots. The results also showed that residual effect of applied chemical fertiliser to soybean plants was not different from one another but seed yields were, in most cases, higher than those of maize plots. The results implied that soybean plants could have contributed some certain amounts of soil nutrients by providing root nodules and plant residues to the soil apart from residual effect of the applied chemical fertilizer. Thus there were no significant effects due to treatments found. Seed yields, in most cases, were higher than those attained from the maize plots. The results suggested that root nodules and crop residues of leaves, stems and branches of soybean plants aided soil fertility level where sunflower plants could be able to provide high seed yields at the end of the experimental period. Therefore, the practice of the growers in using soybean as a main crop may be of an ideal practice for sustainable agriculture. For the results on sunflower treatments (sunflower was used as main crop) of Method 3, the results showed that seed yields between T_1 and T_2 were not different from one another. This may be attributable to some certain amounts of nutrients left in soil when the previous sunflower plants were not able to use a majority amount of soil nutrients due to perhaps its small amount of total dry weight $plant^{-1}$ or it may be possible that the planting distances of the previous sunflower plants were not suitable, i.e., a small value of Leaf Area Index (LAI) of sunflower was attained. Suksri *et al.* (1989) stated that LAI of sunflower plants of horizontal leaf structure should reach a maximum value of 6. With this LAI value, the sunflower plants could be able to use both soil nutrient and radiant energy from the sun more efficiently. Nevertheless, when it comes to the Method 4, i.e., no tillage and no crop being cultivated in the plots before the sunflower seeds were sown. The results showed that seed yield ha^{-1} was much lower than the rest of the three methods used. The results suggested that sunflower plants being grown under this method of cultivation could not be most appropriate method for growers to practice. This could be attributable to many reasons such as (1) the compaction of soil due to no tillage for a certain period of time (2) poor soil aeration with low amount of O_2 available in soil for plant roots and (3) no crop residues were added to the soil to promote microbial activities. Therefore, the practice of Method 4 could not be an appropriate method for growers to implement although investment budget could be relatively low. Seed yields ha^{-1} of the experiment carried out at Saraburi location, in most cases, were higher than the location at Suranaree Technology University Experimental Farm. This may be attributable to amounts of rainfalls where the area of this Korat soil series obviously attained a lesser amount of annual rainfalls than that of Saraburi province, thus drought conditions could have occurred, particularly at a filling stage of seeds. The problem on high value of soil pH at Saraburi site could possible overcome by the use of some large amounts of crop residues being annually added to the soil in order to facilitate the release of soil nutrients where sustainable agriculture could be achieved, otherwise the high value of soil pH may not be an ideal soil type for an annual cash crop. Seed yields of sunflower of both experimental sites were lower than those reported by Suksri *et al*. (1989).

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