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Effect of Splitting the Dose of Phosphate Fertilizers on Phosphorus Availability and Growth and Yield of Cauliflower (*Brassica oleracea* var. Botrytis)

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Abstract: A field experiment was carried out at the Agricultural Research Station College of Agriculture, University of Basra in southern Iraq. It included the response of cauliflower plants to the addition of 60 kg Pha^{-1} in the form of Concentrated Superphosphate (CSP) or Diammonium Phosphate (DAP) fertilizers with four treatments of splitting the level of fertilizer: addition all Fertilizer dose at Transplanting (T1); 50% of the fertilizer level at transplanting and remaining 50% divided into three doses, 10 days apart (T2); 50% of the fertilizer level at transplanting and remaining 50% divided into two doses, 15 days apart (T3); 50% of the fertilizer level at transplanting and remaining 50% is added 30 days after planting (T4). Drip irrigation was used to irrigate the plants grown on bands 0.5m wide and each plot 2m long, containing 5 plants. Each treatment was repeated in three replicates with randomized complete block design. Results showed that the type of phosphate fertilizer did not affect soil pH, but affected the soil salinity; salinity increased in the presence of CSP over DAP. Likewise, Type of phosphate fertilizer had a significant effect on available phosphorus in soil, as DAP fertilizer outperformed CSP at a rate of 97.94 and 83. 63 mg kg^{-1}, respectively. This result significantly affected the superiority of DAP on CSP in plant growth parameters (P in leaves, number of leaves plant-1 and leaf area) and in terms of plant yield and quality (head weight, head diameter, total yield, total dissolved solids, carotene in fruits). For the splitting fertilizer level, T3 treatment surpassed the rest of treatments in available phosphorus in soil, growth parameters and yield parameters and quality of cauliflower plants; total plant yield reached 54.37 and 54.20 tons ha^{-1} with DAP and CSP fertilizers, respectively, with an increase percents of 22.53 and 37.59% compared to the conventional Treatment (T1).

Keywords: Concentrated Superphosphate, Diammonium Phosphate, Available P, Splitting Fertilizer Dose, Cauliflower, Carotene

INTRODUCTION

Iraq is located within dry and semi-arid regions, consisting more than 20% of total area Alwan [1]. Therefore, these regions suffer from a high content of calcium carbonate and a high pH value, which leads to a decrease in the available concentrations of nutrients, including phosphorus. Phosphorus is one of the essential elements for plant growth and productivity controlling soil fertility, plant yield and quality. Phosphorus is involved in formation of nuclear acids, RNA and DNA, energy-transmitting compounds, proteins, cellular membranes and co-enzyme, so its deficiency leads to weak stems, limited root growth, small leaves and delayed fruit ripening Al-Nuaimi [2-3]. Phosphorus in calcareous soils is exposed to many reactions that lead to precipitation and/or formation of unavailable complexes. Salimpour *et al.* [4] stated that the efficiency of phosphate fertilizers does not exceed 20-35% due to its exposure to stabilization and adsorption processes. Tisdale *et al.* [5] explained that benefit of added phosphate fertilizers may reach 10-30% and the reactions velocity with soil components varies depending on soil nature and environmental conditions. Therefore, a deficiency available phosphorus occurs in most agricultural soils in arid and semi-arid areas, such as southern Iraq, which is of a calcareous nature characterized by an abundance of dissolved calcium ions and calcium carbonate content, which will react directly with the added phosphate fertilizers, forming phosphate-calcium compounds (P-Ca).

Farmers in the central and southern regions of Iraq have become accustomed to adding superphosphate fertilizer (and other phosphate fertilizers at the present time) at dose at sowing time to reduce the strong acidic effect on the seedlings and to ensure appropriate initial root growth that helps absorb water and nutrients from the soil solution and increase the plant's biomass early. However, adding full dose may accelerate the phosphorus sorption and precipitation.in such soils. This deterioration, of course, is due to the accumulation of high amounts of phosphorus in soil solution and may accelerate the transformation from sorption, which is less harmful to readiness, to precipitation.

Many attempts have been made to splite the dose of phosphate fertilizer, leading to improving phosphorus availability and increasing plant yield [6,7,8], which is attributed to the plant's need for this nutrient throughout the growing season and the need increases at the stages of maturity and grain filling and/or to reduce fixation rates by decreasing the added dose. Also, the studies involved the splitting process did not cover types of plants, especially vegetables such as cauliflower, which is considered one of the annual plant and is multiplied by grains. It is a vegetable rich in phosphorus, vitamin K and vitamins B. It is used to treat osteoporosis and rickets. Its production in 2016 reached approximately 25 million tons per year globally. It contains a high percentage of folic acid, fibre, proteins and iron. It is one of the healthy plants because it contains flavonoids and glycocytoylphenes, which are rich in sulfur. As a result, this study aimed to divide the dose of phosphorus added from different fertilizer sources to reduce its loss in soil and effect on growth and yield of cauliflower plants grown in calcareous soil.

MATERIALS AND METHODS

A field experiment was conducted at Agricultural Research Station/College of Agriculture/University of Basra, located in the Karmat Ali regions ($47^0$44'40"E and latitude $30^0$33'44"N) during the growing season of 2023-2024 to study the effect of splitting phosphorus level of two types of phosphate fertilizers (triple superphosphate (CSP) and Diammonium Phosphate (DAP)) in available of phosphorus and growth and yield of cauliflower plants.

Composite samples were collected from field to measure initial soil properties (Table 1) and according to the standard methods mentioned in Richards [9] and Page *et al*. [10]. experiment included two factors.

Phosphorus source: Phosphorus was added from two sources:

- Concentrated Super Phosphate (CSP)
- Diammonium Phosphate (DAP)

Splitting the dose of phosphate fertilizer: Phosphorus was added at a level of 60 kg P ha^{-1} from the sources at different times and according to the following:

- **T1:** Full dose 100% at transplanting
- **T2:** 50% dose at transplanting and the remaining 50% divided into 3 doses, 10 days apart
- **T3:** 50% dose at transplanting and the remaining 50% divided into two doses, 15 days apart
- **T4:** 50% dose at transplanting and the remaining 50% added 30 days after transplanting

The experiment was designed as a factorial experiment with a Randomized Complete Block Design (RCBD) and three replications. field was prepared by plowing in two perpendicular plows at a depth of 0.3m, smoothed and leveling operations were carried out. Cultivation was done on a row, distance between row to row was 1m and width of row was 0.5 m. Manure (cow waste) was added at level of 5 ton ha^{-1} at a depth of 0.2m. Field divided into three Blocks, each one contained 8 plots with 5 plants. The distance between plants was 0.4m. drip irrigation system from Shatt al-Arab river was used. White flake cauliflower seedlings were grown in plastic dishes and then transplanting to the field after they reached to three true leaves stage. The experimental units were fertilized with urea (46% N) at rate of 250 kg N ha^{-1} and potassium sulphate (43% K) at rate of 160 kg K_2O ha^{-1}. Phosphorus was added from the two mentioned sources in the bands near the plants. As for nitrogen and potassium fertilizers, they were added in the same way as phosphorus. Nitrogen was added in three doses during the growing season and potassium was added in one dose at flowering stage. All agricultural practices adopted in the region were carried out until the end of the season and harvesting the crop.

Random soil samples were taken from the surface layer of soil (0-30 cm) from each plot, mixed well, air-dried, then ground and passed through a sieve of 2 mm, then analyzed for soil pH suspension (1:1) and soil salinity (EC) in soil extracte (1:1) according to the methods mentioned in Page *et al*. [10]. At the end of the season, the available phosphorus in the soil was extracted with a solution of 0.5*M* $NaHCO_3$ (Olsen), then phosphorus was determined colorimetrically by the method of Murphy and Riley [11]. Leaf samples were taken from two plants for each experimental unit at the vegetative growth stage, then leaf area was estimated. Leaves were cleaned, dried at a temperature of 70°C and digested with an acidic mixture of 4%$HClO_4$ + H_2SO_4 Gresser and Parsons [13] and the phosphorus concentration was estimated colorimetrically according to method of Murphy and Riley [11] after adjusting the acidity of the phosphorus mixture. At the end of the season, the number of leaves for each plant, the curd Weight and curd diameter were recorded. The total curd yield of cauliflower was calculated from the weight of the heads in the plot. The percentage of carotene in the curd was also estimated after crushing part of the curd with80% acetone and measuring at a wavelength of 480 nm. The Total Dissolved Solids (TSS) content measured by placing part of the curd in manual press and measured by a hand refractometer Abbas and Abbas [13]. The treatments were subjected to statistical analysis as a factorial experiment with two factors (type of phosphate fertilizer × fertilizer dose splitting). The data were included in an Analysis of Variance (ANOVA) using the Gen State 18.2 program, then the means were compared using the Adjusted Least Significant Difference (RLSD).

RESULTS AND DISCUSSION

Soil Properties

Table 2 showed the effect of fertilizer source and splitting treatment on the soil pH, EC and available phosphorus. The results indicated that the source of phosphate fertilizer (CSP and DAP) did not have a significant effect on soil pH,ranged between 7.60 and 7.83. These results are similar to results of

Alkhader and Abu Rayyan [14] and Al-Rubaie [15]. Mahmoud and Al-Zubaidi also found that adding phosphate fertilizer did not significantly affect pH of soil grown with cauliflower. On the other hand, the splitting of fertilizer dose led to significant effect indicating that the splitting treatments (T2, T3 and T4) caused a significant decrease in soil pH at a rates of 7.67, 7.73 and 7.70, respectively, compared with conventional Treatment (T1) at a rate of 7.82. The lowest and highest values of the interaction was obtained at T2 interacted with DAP and T1 interacted with DAP respectively. The decrease in pH at splitting treatments may be due to the decrease in phosphorus fixation leading phosphorus in available form for a longer time. Moreover, the splitting ensures the continues of acidic effect (with regard to CSP fertilizer) in lowering pH, as well as activating the ammonium nitrification process in DAP fertilizer, which reduces pH of microsites of soil.

Table 2 indicated that adding phosphate fertilizers with two sources (CSP and DAP) led to a decrease in soil salinity (EC) compared to initial value of 6.12 dSm^{-1} (Table 1) with a value of 3.73 and 2.43 dSm^{-1} for CSP and DAP, respectively. It can also be noted that DAP fertilizer is superior in reducing soil salinity compared to CSP fertilizer at a rate due to the acidic effect of CSP leading to the dissolution of many compounds and salts in soil, in addition to the fact that CSP contains high amounts of calcium (12-14%), which increases salinity of soil compared to the neutrally reaction of DAP.

As for the effect of splitting the fertilizer dose, splitting treatments significantly increased soil EC compared with conventional Treatment (T1) with a values of 1.74, 2.96, 2.69 and 2.94 $dSm^{-1}$for T1, T2, T3 and T4, respectively. The highest salinity values were reached in the T2 split treatment (three doses, 10 days apart), at a rate of 2.96 dSm^{-1}. The CSP fertilizer treatment combined with three doses, 10 days apart (T2), gave the highest soil salinity values at a rate of 3.35 dSm^{-1}. Splitting the fertilizer dose reduces phosphorus precipitation, allowing the fertilizer reaction to continue in adding salts as well as reduces calcium precipitation. It can also be noted that although there are significant differences among splitting treatments for both fertilizers, the differences are still small and do not exceed 1.0 dSm^{-1}.

The results of Table 2 indicated that adding both types of fertilizers (CSP and DAP) led to a significant increase in available phosphorus in soil at values of 83.63 and 97.94 mg kg^{-1}, respectively, compared to the initial soil content of 8.30 mg kg^{-1} (Table 1). The superiority of DAP over CSP may be due to the physical properties of DAP fertilizer, such as the solubility in soil high diffusion coefficient and low ability to clump Jarallah and Al-Janabi [13]. This was confirmed by the results of Ibrahim [16], who obtained the superiority of DAP over CSP at a rate of 57.15 and 50.20 mg kg^{-1}, respectively. A significant increase in available phosphorus was observed when splitting the fertilizer dose with values of 49.42, 101.16, 122.02 and 90.06 mg kg^{-1} for treatments T1, T2, T3 and T4 indicating the superiority of Treatment (T3). The interaction effect indicated the highest value of available phosphorus (130.79 $mgkg^{-1}$) was obtained with using DAP along with treatment T3 (3 dose). Al-Absawi [6] also attributed the superior effect of splitting the phosphate fertilizer and adding it in two doses (T3) instead of one dose at planting can reduce the chances of adsorption and precipitation reactions, then consequently increase available phosphorus in soil.

Table 1: Some chemical and physical properties of soil

Property		Value	Unit
pH (1:1 in Water)		7.70	-
Electrical Conductivity (EC)		6.12	dSm^{-1}
Available Nitrogen		32.64	mg kg^{-1}
Available phosphorus		8.30	mg kg^{-1}
Available potassium		120.60	mg kg^{-1}
Total Carbonates		232.0	g kg^{-1}
CEC		14.00	Cmol+kg^{-1}
Organic matter		2.43	g kg^{-1}
Soluble cations	Calcium	16.5	mmol L^{-1}
	magnesium	11.00	%
	Sodium	21.3	
	bicarbonate	13.6	
	sulfate	18.50	
	chloride	28.00	
Soil particles Size	sand	38.80	
	loam	40.00	
	clay	21.20	
Soil texture		loam	

Table 2: Effect of splitting dose of CSP or DAP on some soil properties

Parameters	CSP				DAP				RLSD		
	T1	T2	T3	T4	T1	T2	T3	T4	F	T	F×T
pH	7.81	7.73	7.65	7.75	7.83	7.60	7.81	7.64	NS	0.103	0.113
EC (dSm^{-1})	1.45	3.35	3.11	3.03	2.02	2.57	2.28	2.85	*	0.10	0.141
P available ($mgkg^{-1}$)	60.07	110.75	113.26	50.45	38.78	92.54	130.79	129.67	*	2.65	3.74

CSP: Concentrated Super Phosphate; DAP: Diammonium Phosphate; T1: Full dose 100% at transplanting.); T2: 50% dose at transplanting and the remaining 50% divided into 3 doses, 10 days apart.; T3: 50% dose at transplanting and the remaining 50% divided into two doses, 15 days apart; T4: 50% dose at transplanting and the remaining 50% added 30 days after transplanting

Table 3: Effect of splitting dose of CSP or DAP on some growth parameter of cauliflower

Parameters	CSP				DAP				RLSD		
	T1	T2	T3	T4	T1	T2	T3	T4	F	T	F×T
P plant (gkg^{-1})	0.95	1.35	1.56	1.27	1.38	1.44	1.83	1.40	*	0.033	0.047
Leave number (leaves $plant^{-1}$)	16.00	18.00	19.00	17.00	18.00	18.67	18.00	18.67	NS	0.95	1.34
Leaf area (cm^2)	43.16	43.56	44,09	38.87	47.24	51.91	59.10	46.11	*	1.50	2.12

CSP: Concentrated Super Phosphate; DAP: Diammonium Phosphate; T1: Full dose 100% at transplanting.); T2: 50% dose at transplanting and the remaining 50% divided into 3 doses, 10 days apart.; T3: 50% dose at transplanting and the remaining 50% divided into two doses, 15 days apart; T4: 50% dose at transplanting and the remaining 50% added 30 days after transplanting

Plant Growth Parameters

A result of Table 3 indicated that adding DAP fertilizer resulted a higher P concentration in leaves compared with CSP fertilizer with a mean value of 1.51 and 1.28 gkg^{-1} respectively. This was due to the higher amount of available phosphorus in the soil (Table 2). The results also indicated that splitting fertilizer dose led to a significant difference between the treatments. With a highest value (1.69g kg^{-1}) at Treatment (T3). The interaction of DAP with the split treatment T3 gave the highest value of phosphorus in the plant, reaching 1.83 g kg^{-1}. The reason for the superiority of splitting treatments over conventional addition can be attributed to increasing available phosphorus by reducing the loss through sorption and precipitation processes and as a result, increasing its concentration in the plant.

Adding DAP fertilizer led to a significant increase in leaf area and number of leaves per plant compared to CSP fertilizer (Table 3), with an average of 51.09, 42.42cm^2 and 18.33,17.50 leaves $plant^{-1}$ for the two fertilizers, respectively. The reason for the superiority of DAP fertilizer can be attributed to high ability to supply plant with phosphorus (Table 3). Sami and Maha explained the superiority of DAP fertilizer over the rest of phosphate fertilizers. phosphorus playing It plays an important role in the growth and development of plants, as it stimulates cell division and build cell membranes through its involvement in the formation of energy-rich compounds (ATP, GTP and CTP). It may also be attributed to the participation of phosphorus in the decomposing carbohydrates and other substances resulting from photosynthesis, liberating the energy for the plant's metabolism and helping in the formation of amino acids, the basic constituent for building plant cells Devasagayam and Jayapaul [17]. Phosphorus also plays an important role in increasing chlorophyll, thus improving the efficiency of the photosynthesis process by increasing the absorption of magnesium, which is involved in the formation of chlorophyll Blevian [18]. In addition to the role of phosphorus in forming a strong and large root system, resulting in an increase in the amount of nutrients uptake and accumulated in the leaves Jackson [19] and their participation in building new cells. These results were similar to the results of Al-Rubaie [15]. Alkhader *et al.* [20] attributed this superiority to the presence of ammonium ion with phosphorus in the same fertilizer lowers the pH and increases uptake of phosphorus, which is reflected in dry matter production and vegetative growth.

The results also show that despite the increase in leaf area when the fertilizer dose was splitted, the differences were not significant for CSP fertilizer, with values of 43.56, 44.09 and 38.87 cm^2 for treatments T2, T3 and T4, respectively, compared to the T1 treatment with value of 43.16 cm^2. In contrast, splitting of DAP fertilizer dose led to a significant difference between treatments T2, T3 and T4, with values of 51.91, 59.10 and 46.11 cm^2 for the treatments T2, T3 and T4, respectively, compared to the Treatment (T1) at a rate of 47.24 cm^2. However, number the leaves are in the opposite trend to the leaf area. The T3 split treatment gave the highest leaf area and leaves $plant^{-1}$ for both fertilizers and this result attributed to highest available phosphorus and concentration of phosphorus in leaves.

Plant Yield Parameter

The results of Table 4 showed that DAP fertilizer gave more values than CSP fertilizer in the characteristics of head weight, head diameter and total plant yield, with an values of 1746.75 g, 20.41 cm and 47.78 tons ha^{-1} for DAP and 1525.75 g, 19.27 cm and 44.45 tons ha^{-1} for CSP. The superiority of DAP fertilizer is due to its superiority in plant growth component and phosphorus content (Table 3). These results were similar to Uddain [21] in his study of the effect of phosphorus on cauliflower plants. The results indicated T3 treatment, which included dividing the fertilizer level into 3 doses outperformed the rest of splitting treatments and was significantly superior to conventional Treatment (T1), with an increase percents of 14.74, 3.83 and 29.60% for head weight, head diameter and total plant yield, respectively. When reviewing the interaction of the two study factors, it is noted that the superiority of the T3 treatment was for both fertilizers and for all the studied parameters and these results were consistent with the growth parameters reported in Table (3). To confirm that the S yield and yield components are a function of the plant growth and phosphorus uptake. These results were similar to Al-Absawi [6], who obtained an increase in the yield of two types of wheat when phosphorus level was divided into two doses instead of adding it as a single dose.

The results showed a significant effect of the type of phosphate fertilizer on the qualitative characteristics of cauliflower yield (% total dissolved solids TSS and amount of carotene) (Table 4). DAP was significantly surpassed to CSP with an average of 4.12% and 11.58 mg 100 g^{-1} fresh weight for DAP and 3.86 % and 10.72 mg 100 g^{-1} fresh weight of CSP. As for the effect of phosphorus splitting treatments, T3 treatment significantly gave the highest. Over other treatments for the two fertilizers. Highest values of TSS and carotene content (4.20% and 12.64 mg 100g^{-1} fresh weight) appeared when T3 treatment was combined with the addition of DAP fertilizer, which was stated in growth parameters (Table 3) and yield parameters (Table 4).

Table 4: Effect of splitting dose of CSP or DAP on Plant yield parameters of cauliflower

Parameters	CSP				DAP				RLSD		
	T1	T2	T3	T4	T1	T2	T3	T4	F	T	F×T
Curd weight (g)	1433	1197	1971	1502	1849	1845	1850	1443	*	31.16	44.93
Curd diameter (cm)	19.70	18.15	20.91	18.35	19.97	21.66	20.28	19.75	*	NS	1.35
Curd yield (tonha^{-1})	39.39	42.42	54.20	41.31	44.37	50.73	54.37	41.68	*	1.15	1.65
TSS (%)	3.30	4.07	4.00	4.10	4.40	3.90	4.20	4.00	*	0.46	0.39
Carotene (mg100g^{-1}Fm)	10.46	11.03	12.65	8.71	10.95	11.18	12.65	11.73	*	2.16	3.06

CSP: Concentrated Super Phosphate; DAP: Diammonium Phosphate; T1: Full dose 100% at transplanting.); T2: 50% dose at transplanting and the remaining 50% divided into 3 doses, 10 days apart.; T3: 50% dose at transplanting and the remaining 50% divided into two doses, 15 days apart; T4: 50% dose at transplanting and the remaining 50% added 30 days after transplanting

Increasing phosphorus uptake and other nutrients such as N and K will help, increase the rates of photosynthesis and formation of compounds such as carbohydrates, amino acids and salts of organic acids, which are transferred to the fruits then increase the TSS. This characteristic is a measure of the nutritional value of the fruits. Improving plant growth due to appropriate fertilization in terms of the type of fertilizer and addition time can improve photosynthesis and the production of metabolites and pigments such as carotene, which is important in the process of absorbing light.

CONCLUSION

We can conclude from this study that DAP fertilizer is superior to CSP fertilizer available amount of phosphorus in soil, which had a positive effect on growth parameters, yield and qualitative parameters of cauliflower plants.so, it can be used in calcareous soils as an alternative to CSP fertilizer, which has stopped being manufactured locally. The dose of phosphate fertilizer can be divided into three doses, half of the level is added at planting stage to ensure root growth and help in the formation of the plant's primary leaves and the other half is divided into two doses with an interval of 15 days to ensure a reduction in phosphorus fixation to make most of the fertilizer dose available until the time of flowering and maturity.

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