ISSN : 2028-2508
CODEN: JMESCN

Assessment of cadmium and its impact on the uptake efficiency of Phosphate fertilizers by *Amaranthus tricolour*

M. Kumar [1], K. Sridevi [2], R. Tamilarasan [1]*

[1]*Department of Chemistry, Anna University of Technology, Tiruchirappalli (Pattukottai Campus), Rajamadam-614 701, India.*

[2]*Department of chemistry, Kurinji College of Arts and Science, Tiruchirapalli-2.*

Received 28 March 2012, Revised 12 July 2012, Accepted 12 July 2012
* Corresponding author: Email: rrtamilk@yahoo.co.in

Abstract

Phosphorus is a most essential plant nutrient; its deficiency in soils is severely affecting the growth of crop production. A batch mode RBD (Randomized block design) study was carried out to assess the efficiency of water and citric acid soluble various phosphate fertilizers in soils and their uptake efficiency by using the plant, *Amaranthus tricolour* variety. The various soil samples are analyzed before and after the application of fertilizer. The leaf (green and dry) samples of the plant at two different growth stages (20 & 35 days) of plant and dry matter production (20 & 35 days) of plant were collected, analyzed, calculated and expressed in t/ha. The performance of each fertilizer and their efficiency were assessed by applying various quantities of phosphate fertilizers and its results of the study showed that the presence of toxic metals like cadmium in the soils has been reduces nutrient uptake capacity of the plant considerably. This trend was increases with the accumulation of more stable forms of cadmium in the soil. The observed results indicate that the uptake efficiency of phosphate fertilizers increases with applying very high quantity of phosphate in the presence of cadmium. The action of cadmium is seen at the whole plant level in reduced growth.

Keywords: Phosphate, assessment, efficiency, amaranthus tricolour

1.Introduction

Most of the Amaranthus species have edible leaves, and the varieties of species are widely used as potherbs (boiled greens). Over the years, growers have selected types with leaves and stems of high palatability. Their mild spinach-like flavour, high yields, ability to grow in hot weather and high nutrient value have made them popular vegetable crops, perhaps the most widely eaten vegetables in the humid tropics. In humid tropical Africa, Amaranthus cruentus is extensively grown as a leaf vegetable, Amaranthus tricolour is also a popular cultivable variety grown in most of the places in India. Green leafy vegetables are known to contain a wide variety of anti-nutritional factors [1-5]. The Role of Amaranthus an under exploited plant with promising economic value, and it has been recently recognized by the National Academy of Sciences [6, 7].N, P and K are major plant nutrients, among these phosphorous plays an important role in the root development of the plants as well as for the synthesis of protein, fats and carbohydrates [8] of the plants. Phosphorous is available in different forms of fertilizers in the market. They are Single super phosphate, Double super phosphate, Triple super phosphate, Mono ammonium phosphate, Di-ammonium phosphate, Mono potassium phosphate, Rock phosphate, Mono calcium phosphate, Di-calcium phosphate, Basic slag, Calcium Meta phosphate and Bone meal.

Phosphate fertilizers are manufactured by different factories (or) industries and produced by various processes with different combinations of raw materials. Their availability and efficiency are influenced

based on their production, solubility, mode of preparation, method of application as well as the presence of other elements especially heavy metals [9-13].
Trace elements and heavy metals occur naturally in all agricultural soils; most of them are either essential or beneficial to the plants [14]. However they can become toxic, if accumulated in excess amount in the fertilizer. Which results when both agronomic and environmental conservation are included in the development of nutrient management plant which can prevent (or) greatly reduced the potential for such toxicity [15, 16]. Cadmium (Cd) is one of the important toxic heavy metal present in the environment. It is easily absorbed by roots and translocated to different plant parts and enters the human food chain [17, 18].

Table-1. Solubility behaviour and percentage of phosphorous content in the fertilizers

Solubility	Name of the fertilizer	P_2O_5 (%)
Water soluble	Single super phosphate $(CaH_2PO_4)16$	18
	Double super phosphate $CaH_4(PO_4)_2$	32
	Triple super phosphate $Ca(H_2(PO_4))_2$	46 – 48
	Ammonium Phosphate $(NH_4)_3PO_4$	20
Citric acid soluble	Dicalcium phosphate $CaHPO_4$	14
	Basic slag $(CaO)_5P_2O_5.SiO_2.17$	20
	Calcium meta phosphate $Ca(PO_3)_2$	60 – 64
Water and citric acid insoluble	Rock phosphate $Ca_3(PO_4)_2$ $2CaF_2$	20 – 30
	Bone meal $(Ca(PO_4)_2)_3$ CaF_2	20 – 21

In recent years various research reports shows that the heavy metal contamination of the fertilizers and their ill effects to the plant. The reason for the contamination of fertilizer is due to the manufacturing methods and from industrial by-products. Among the various heavy metals, cadmium is naturally occurs in phosphatic rock, which is commonly used to produce phosphorous fertilizers [19]. During the manufacturing process, much of the cadmium is carried through to the final fertilizer product. Phosphatic rock contains other metals and various radio nuclides as a minor constituent in the minerals. Different quantities of these elements are transferred into phosphorous fertilizers through the production processes and later which are applied to soils along with fertilizers. The application of cadmium to the soil through the fertilizers and the subsequent uptake by the crops and concentration of the other heavy metals and radionuclide contaminants in phosphorous fertilizers varying at considerable amount which may depends on the sources. The other heavy metals found in the fertilizers are arsenic, chromium, lead, mercury, nickel and vanadium [20-24]
Heavy metal contaminants in phosphorous fertilizer may be available in the soil and taken by the plants. Cd is very immobile so it tends to accumulate in the surface soil [25]. The phosphorous fertilization is the major route for the direct supply of nutrient (and indirect supply of heavy metals) to the plants; therefore these fertilizers are added to the soil. Vegetables and fruit crops are more heavily fertilized than that of field crops, so the accumulation of heavy metals to be greater in vegetable cultivated soils [26]. The availability of the metals to the plants is related to its solubility in the phosphorous fertilizer as well as soil factors such as pH, CEC (Cation Exchange Capacity), clay fraction and organic matter contents. Plants vary in their capacities to absorb and translocation of these metals [27-32]. Among various inputs in agricultural production the fertilizers represents a substantial expenditure for farmers, applying the optimal fertilizer rate and increasing the efficiency of fertilizer is critical for profitable forming.
Therefore the objective of the present study is, to find out the efficiency and nutrient uptake capacity of phosphate fertilizer (Fertilizer efficiency)in the soil. A batch mode RBD (Randomized block design) study was carried for the efficiency of water and citric acid soluble various phosphate fertilizers in soils and its uptake efficiency was assessed by using *Amaranthus tricolour* variety. The various soil samples are analyzed before and after the application of fertilizer. The leaf (green and dry) samples of the plant at two different growth stages (20 & 35 days) of plant and dry matter production (20 & 35 days) of plant were collected, analyzed, calculated and expressed in t/ha. The right selections of phosphorous fertilizer sources are avoid the heavy metal accumulation in soil system. The efficiency of fertilizers is high, then the deleterious effect of metals in the plant system and through the human health system are gradually decreases.

ISSN : 2028-2508
CODEN: JMESCN

Table-2. Different forms of fertilizers.

P_2O_5 source	N	P_2O_5 %		
		Total	Available	H_2O soluble
Super phosphate (OSP)	0	21	20	85
Mono ammonium phosphate (MAP)	11	49	48	82
Concentrated super phosphate (CSP)	0	45	45	85
Di ammonium phosphate (DAP)	18	47	46	90
Ammonium poly phosphate (APP)	10	34	34	100
Rock phosphate	0	34	38	0

2. Materials and Methods

The field trial was conducted during Rabi-summer season (Oct 2011-Jan 2012) at Agricultural Research Farms, Thanjavur, District, India. And The soil laterite sample containing, low organic carbon, nitrogen and medium phosphorous, potassium with acidic in nature was chosen in this experimental study. The trial was conducted in RBD (Randomized block design) with the treatment consists of different source of phosphorous (Table- 3) applied with equal nutrient quantity required for normal package of practices and replicated thrice. The test crop was Amaranthus variety arun. The detail of plot layout is depicted in Fig- 1. Recommended cultural practices were followed in all the plots except nutrient management. The soils samples before sowing and after harvest of the crop, the plant sample at two different stages (20 & 35 days) of plant and dry matter production of 20 & 35 days of plant were collected, analyzed, calculated and expressed in t/ha.

2.1 Crop culture

The general procedures of Amaranthus cultivation were followed in the experimental field. The experimental area was ploughed up to 4 times to get the fine tilth. The layout was designed as per the individual experiments. The ridges and furrows were formed at 30cm spacing and 25 days old seedlings were transplanted at 20cm spacing and recommended the phosphatic fertilizer was applied as per the treatment.

2.2 Analysis

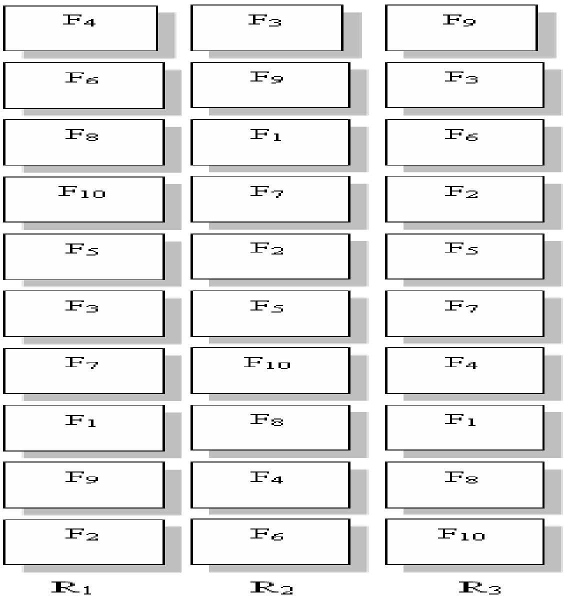
2.2.1 Soil analysis

Soil samples were collected from the experimental plot before cropping and after harvest of the crop were dried, crushed the clods and passed through 2mm sieve and analyzed the availability of P and other metals.

2.2.2 Plant analysis

For chemical analysis of plant, the samples were selected at randomly from the destructive sampling area of each plant at harvest. The samples were dried in a hot air oven for 72 hours at 60^0C (±5),cooled and ground into powdered form by using hand crushing method then analyzed the nutrient contents by standard methods. The methods are used for the analysis of soil and plants are given in Table - 4. Shoot tissues were collected and thoroughly washed with deionised water then dried up to a constant weight and ground in a titanium centrifugal mill. Metal concentrations in the plant tissue samples (290 – 310 mg dry weight) were determined using an acid (65% HNO_3) dissolution technique with microwave heating and then it was analyzed by using Flame – Atomic Absorption Spectroscopy. Heavy metal concentrations in leachates were determined by using Flame – Atomic Absorption Spectroscopy.

ISSN : 2028-2508
CODEN: JMESCN



R_1- Plot column 1, R_2- Plot column 2 and R_3- Plot column 3
Figure-1. Plot layout of treatment details for various phosphate fertilizers

Table-3.Treatment details of phosphate fertilizers

S. No	Treatment	Particulars	Quantity
1	F_1	Single super phosphate	277kg/ha
2	F_2	Double super phosphate	156kg/ha
3	F_3	Triple super phosphate	110kg/ha
4	F_4	Ammonium phosphate	250kg/ha
5	F_5	Dicalcium phosphate	375kg/ha
6	F_6	Basic slag	250kg/ha
7	F_7	Calcium meta phosphate	84kg/ha
8	F_8	Rock phosphate	200kg/ha
9	F_9	Bone meal	250kg/ha
10	F_{10}	Control (without P fertilizer)	-

Table-4. Methods of analysis of plant and soil

S.No.	Nutrient	Method	Reference
1	Soil phosphorous (available P_2O_5)	Ascorbic acid reduced molybdo phosphoric blue colour (kg/ha)	Watanabe and Olsen (1965)
2	Trace elements	0.1NHcl exact method using at absorptrai spectro photometry	Jackson (1958)
3	Plant phosphorous	Diacid extract estimated colorimatrically in a spectronic – 20 spectrometer by vanedomolybdo phosphoric yellow colour	Jackson (1958)
4	Trace elements	Diacid extract method using atomic absorption spectrophotometer	Jackson (1958)
5	Heavy metals	Atomic adsorption Spectrophotometer (AAS)	

ISSN : 2028-2508
CODEN: JMESCN

2.2.3 Efficiency analysis

Ten plants were collected; dried and estimated dry matter production was expressed in t/ha. The physiological efficiency was calculated by using the following formula:

$$\text{Physiological efficiency} = \frac{\text{Total dry matter yield of fertilized crop(kg)} - \text{Total dry matter yield of unfertilized crop(kg)}}{\text{Nutrient uptake of fertilized crop(kg)} - \text{Nutrient uptake of unfertilized crop(kg)}}$$

Results and Discussion

The field experiment was carried out at agricultural farms. The efficiency of phosphatic fertilizers in Amaranthus plant results was presented.

3.1 Plant growth characters

The green matter production of plant at harvest was observed and dry matter production were calculated and also presented in table-5. Among different sources of fertilizer the dicalcium phosphate is the highest green matter as well as dry matter production per plant was observed. The least green matter production of 468 g/plant and dry matter production of 0.578 g/plant was recorded in control plant (without phosphatic fertilizer). The application of different sources was significantly influenced on growth characters, when compared to control plant. The different sources the citric acid soluble as well as water, citric acid insoluble fertilizers has contributed positively on the growth characters of the plants. The water soluble phosphorous sources also significantly influence on the growth characters due to the acidic nature of the soil.

3.2. Phosphorous content and uptake

The data on nutrient content of the plant and their uptake efficiency of the crop is presented in the table-6. The highest phosphorous content of 0.724 % and uptake of 0.777g/plant was recorded in the source of dicalcium phosphate. The least phosphorous content and their uptake were recorded in the control plant. The influence on the availability by the presence of calcium and neutralising behaviour of the phosphorous sources has positively influenced on their availability in the plant consequently higher growth character associated for the higher uptake. Due to the acidic nature of the soil, control plant shows that the negative results for the uptake efficiency of the plant. Soil pH highly influences the availability of phosphorous in plants. In tropical soil contains rich iron and aluminium, which possesses high fixing capacity of phosphorous in low pH. Phosphorous is highly soluble in the pH range of 6-7, the pH is greater than 7, presence of calcium significantly reduce the phosphorous solubility in acidic soils [33]. B.R.singh reported that by the change of the soil pH, the uptake of the nutrient also gets increased. The pH of the soil is above 6.5 the minerals uptake capacity of the plant consecutively got increased [34].

Table-5. Effect of different source of phosphorous for green and dry matter production of Amaranthus.

Treatment	Green matter production (g/plant)	Dry matter production (g/plant)
F_1	605.00	0.734
F_2	618.00	0.753
F_3	712.00	0.872
F_4	746.00	0.904
F_5	878.00	1.080
F_6	636.00	0.758
F_7	828.00	1.006
F_8	854.00	1.020
F_9	724.67	0.879
F_{10}	468.00	0.578
SEm±	128.16	0.154
CD (5%)	S	S

SEm± : standard mean of error CD : Column deviation

Table-6. Effect of different sources on phosphorous content and uptake of plant

Treatment	Phosphorous content (%)	Phosphorous uptake (%)
F_1	0.470	0.345
F_2	0.510	0.384
F_3	0.540	0.470
F_4	0.660	0.592
F_5	0.720	0.777
F_6	0.690	0.523
F_7	0.680	0.684
F_8	0.610	0.631
F_9	0.530	0.466
F_{10}	0.420	0.242
SEm±	0.103	0.164
CD (5%)	S	S

SEm± : standard mean of error CD : Column deviation

3.3. Cadmium content and uptake

Most of the heavy metals are influencing the nutrient availability and growth performance. The heavy metal cadmium and their effect of plants were studied by various researchers [35-38]. The cadmium supplied or transmitted to the soil through various phosphorous sources. The content of cadmium and uptake is presented in the table-7. The highest cadmium content of 8.246 microgram per kg of plant was recorded in water soluble phosphorous source of ammonium phosphate and the uptake of 7.546 microgram per kg of plant was recorded in calcium meta phosphate. The phosphorous source of single super phosphate from direct mining and their application has helped in the more accumulation of cadmium in the soil as well as in the plant system due to the incomplete processing of the raw material, eventhough the high content in the ammonium phosphate and their lower influence of the growth character resulted in the lower uptake [39]. The least cadmium content and their uptake were recorded in the control plant due to the non application of cadmium containing phosphorous sources. Majid *et al*. reported that the accumulation of cadmium content of the soil gets increased while the quantity of fertilizer application of the soil increases [40].

Table-7. Effect of different sources on cadmium content and cadmium uptake of plant

Treatment	Cadmium content (%)	Cadmium uptake (%)
F_1	8.246	6.006
F_2	7.703	5.816
F_3	6.233	5.383
F_4	7.800	6.996
F_5	5.200	5.606
F_6	7.100	5.376
F_7	7.500	7.546
F_8	6.243	5.986
F_9	5.533	5.150
F_{10}	8.100	4.673
SEm±	1.076	0.857
CD (5%)	S	S

SEm± : standard mean of error CD : Column deviation

3.4. Efficiency analysis

The efficiency analysis of different sources of phosphorous was calculated and presented in the table-8. The highest physiological efficiency of phosphorous was recorded in the water soluble and water insoluble has positively influenced on the higher efficiency of phosphorous. But in the case of cadmium efficiency is vice versa. Perez *et al*. found that vegetable leaf shows higher amount of Cd accumulation rather than the grains and vegetables. The total recoverable Cd concentration in plant (Cd plant), μg/kg dry weight was ranged from 22 to 161 in wheat, and 63–283 in potato (3 years field study) [41]. The results were compared with our study the amount of Cd present in the range of 0.12 to 1.688μg/kg (20 and 35 days). This variation in the amount of cadmium arises because of the duration in the cultivation of the plant. This behaviour associated for the higher productivity reducing the heavy metal accumulation.

Table-8. Physiological efficiency of phosphorous and cadmium

Treatment	Phosphorous (micro gram)	Cadmium (microgram)
F_1	1.604	0.121
F_2	1.217	0.190
F_3	1.291	0.520
F_4	0.915	0.284
F_5	0.966	0.503
F_6	0.646	0.278
F_7	0.971	0.163
F_8	1.180	0.364
F_9	1.354	1.688
SEm±	0.283	0.482
CD (5%)	S	S

SEm± : standard mean of error CD : Column deviation

4. Conclusion

The commercialization of the fertilizer utilization encouraged to being phosphate fertilizers from different mining industries. The influence of different phosphorous sources for the productivity of Amaranthus crop and negative influence for the accumulation of heavy metals (Cd) and its different sources are utilised as well as assessed by using Amaranthus as a test crop. The study revealed that, the increase of the productivity of crop with the reducing of the cadmium metal accumulation by the use of phosphate fertilizers. The acidic nature of the soil is important for the processed and slowly released phosphorous fertilizers. The calcium and neutralized mineral containing phosphorous fertilizer has played an important role for the replenishment of the exhausted phosphorous content in the soil. Citric soluble, water and citric soluble source of phosphorous is more important than the water soluble phosphorous sources under acidic nature of the soil, but the application of phosphorous source alone can help to reduce the nonaccumulation of heavy metals in the cultivable soil system. So the right selection of processed phosphatic fertilizer is important to improve the crop production as well as to reduce the accumulation of heavy metals and their negative impact on the soil and environment system. The higher physiological efficiency showing phosphorus sources also favourable for the more accumulation of heavy metals.

References

1. Abbott, JA., Campbell, TA., *Hort Science*. 17 (1982) 409.
2. Usarat, T., Chongrak, P., *J. of Hazar. Mater*. 165 (2009) 1109.
3. Dhan Prakash., Pal M., *J. of the Sci. of Food and Agriculture*. 57 (1991) 4.
4. Sheetal Gupta., Jyothi Lakshmi, A., Manjunath, MN., Jamuna Prakash., *LWTF Food sci. and tech*. 38 (2005) 4.
5. Sudhir Shukla., Vibha Pandey, G., Pachauri, B.S., Dixit, R., Banerji and Singh, S.P., *Plant Foods for Human Nutrition (Formerly Qualitas Plantarum)*. 58 (2004) 1.
6. NAS., *Natl. Acad. of Sciences, Washington, DC*. (1975).
7. NAS., *Natl. Acad. of sciences, Washington, DC*. (1984).
8. Tsvetkova, GE., Georgiev, G I., *Bulg. J. plant physiol*. (2003) 331.
9. De Lopez Carnelo, LG., De Miguez, SR., and Marban, L., *Total Environ*. 204 (1997) 245.
10. Hill, RM., Rawate, RI., *J. Agric. Food Chem*. 30 (1982) 465.
11. IARC., *International Agency for Research on Cancer, New Delhi*. (1993).
12. Kadar, M., *Horticultural research, Tamil Nadu Agricultural University, Perumbarai*. (1992).

ISSN : 2028-2508
CODEN: JMESCN

13. Cisse., Mrabet, T., *Research Bulletin*. 15 (2004) 21.
14. Chang, A.C., Page, A.L., *California Agriculture*. 54 (2000) 49.
15. Obrenovic, IS., *Biochem. Physiol. Pflanzen*. 178 (1983) 625.
16. Oke, OL., *In proceedings of the second Amarnath Conference, Rodale Press Emmaus, PA*. (1980) 22.
17. Baek, K. H., Chang, J. Y., Chang, Y. Y., Bae, B. H., Kim, J., Lee, I. S., *J. of Environ. Biology*. 27 (2006) 316.
18. Xiao, X., Tongbin, C., Zhizhuang, A., & Mei, L., *J. of Environ. Sci*., 20 (2008) 62.
19. Gregory Mullins., Wade Thomason., *Crop and Soil Envi. Sci*. (2009).
20. Gimeno Garcia, E., Andreu, V., Boluda, R., *Environ. Pollut*. 92 (1996) 19.
21. CDFA., *California Department of Food and Agriculture*. (2004).
22. Zhang, J., Shu, WS., *J. Plant Physiol. Mol. Biol*. 32 (2006) 1.
23. Singh, H., *Indian Council of Agricultural research, New Delhi, India*. 70 (1994).
24. Wills, RBM., Wong, AWK., Scrivwen, FM., Greenfield, H., *J. Agric. Food Chem*. 32 (1984) 413.
25. Mortvedt, JJ., Osborn, G., *Soil science* 43 (1982) 134.
26. Singh, S., Zacharias, M., Kalpana, S., Mishra, S., *J. Envi. Chemistry and Ecotoxic*. 4 (2012) 75.
27. Grubben, GJH., Van Sloten, DH., *International Board for plant Genetic Resources, Food and Agriculture Organization of the United Nations, Rome, Italy*. 57 (1981).
28. Haas, P., Kauffman, C.S., *Regenerative Agric. Assoc., Emmaus*, PA. (1984).
29. Hauptli, H., Jain, S. K., *J. of Heredity*. 7 (1980) 290.
30. Ruijuan Qu., Jiaqi Shi., Dinglong Li., Zhongbo Wei., Xi Yang., Zunyao Wang., *Environment and Pollution*. 1 (2012) 1.
31. Watanabe, FS, Olsen, SR., Soil Sci. Soc. Am. Proc. 29 (1965) 677.
32. Jackson, M. L., Soil Chemical Analysis: Prentice-Hall, Englewood Cliffs, N.J., 498 (1958).
33. Willy verheye., *Encyclopedia of life support systems*. (EOLSS)-4.
34. Singh, B. R., Kristen Myhr., *Geoderma*. 84 (1998) 185.
35. Rehman, F., Khan, FA., Varshney, D., Naushin, F., Rastogi., *J. Biology and Medicine*. 3 (2011) 187.
36. Imran, HS., Wei, K., Jilani, G., Zh, G., *J. of Zhejiang University of Science*. 8 (2007) 181.
37. Mediouni, C., Benzarti, O., Tray, B., Ghorbel, MH., Jemal, F., *Agro Sustainable Development*. 26 (2006) 227.
38. Sun, Y., Zhou, Q., Chunyan, D., *Bioresource Technology*. 99 (2008) 1103.
39. Nalan Turkoglu., Sevket Alp., Arzu Cig., *American-Eurasian J. Agric. and Environ. Sci*. 4 (2008) 595.
40. Nik M. Majid., M.M. Islam., Redzuan Abdul Rauf., Parisa Ahmadpour., Arifin Abdu. *Acta Agriculturae Scandinavica Section B- Soil and Plant Science*, 62 (2012) 245.
41. Perez, A. L., Anderson, K. A. *Science of the Total Environment*. 407 (2009) 5096.