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# INVESTIGATION ON THE UTILIZATION OF COAL FLY ASH AS AMENDMENT TO COMPOST FOR VEGETATION IN ACID SOIL

PROGRESS REPORT

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# INTRODUCTION

This is the second progress report that is submitted to the Department of Energy on the research performed during the second year of the project (DOE GRANT No. DE-FG09-88SR18047) that continued from June 1, 1909. Work carried out during the first year of the project up to March 15, 1989 has been reported in the previous report (Ref. 1). Most of the methodologies that are being used in our research have also been described in detail in that report. The schedule for the execution of the project had to be changed some what due to problems and questions that arose during the first year of the project. It was found that the fly ash (SRS 484-D) does not have an impact on the commercial fertilizer, "Gotta Grow" purchased from Bricker's farm, that was used for composting (Ref: 1). It was also found that the maximum yield for mustard greens and for collard greens planted in the winter of 1988, using the fly ash-amended "Gotta Grow" compost occurred with 5% and 10% fly ash in the compost, respectively. It is also to be pointed out that only 100 g of fly ash-amended compost per 7 kg of soil was used to make the bed for sowing the seeds.

For effective use of fly ash as amendment to compost it was felt that the treatment parameters such as fly ash to compost ratio, fly ash-amended compost to soil ratio, type of compost used for treatment etc. should be optimized for maximum yield of the plants. It is also possible that fly ash-amended compost is more effective to certain plants than others so that different plants have to be grown using the prescribed fly ash-amended compost and compost/soil ratio.

Two papers on our work were presented at Scientific meetings during

1989 academic year and one was accepted for publication in an International journal,"Water, Air and Soil Pollution". Three papers have been accepted for presenatation this year out of which two will be presented at the International conference on "metals in soils, waters, plants and animals" which is scheduled for April 30 - May 3 in Orlando, Florida and the other at the Georgia Academy of Science meeting to be held on May 4 - 5, in Macon, Georgia. Dr. Domy C. Adriano of Savannah River Ecology Laboratory continues to be our consultant for the project and supplier of any additional material we may need for the successful implementation of our project. This report gives a brief summary of the various phases of our research performed during the reporting period, March 16, 1989 to April 15, 1990.

## EXPERIMENTAL METHODS

1. Acquisition of New Equipment and Material: A complete water purification system consisting of Corning "Mega-Pure" Still MP-3A, Corning model 3524-DF Deionizer, Mega-Pure DF system and Automatic Collection Bottle for Still, model MP-3A, 12 gallon capacity was acquired during the latter part of spring,1989 to prepare and store maga-pure water (purity: 1.2 umho). This water is being used for preparing solutions, preparing fly ash-amended composts and watering the plants. A Twin-Shell standard solid-solid Blender, model SB-8, with a material density of 135 lbs/cu.ft and a total volume of 14.6 quts. was also purchased from Patterson and Kelley Co. This blender is particularly useful to mix the fly ash-amended compost and soil to achieve a uniform distribution of the compost in the soil. The sunlight coming out of the roof-glasses of the greehouse was so intense, during the summer months,

that the inside temperature rose above 100° F. Jeff Klein & Sun Co. provided 10 section Saran Rollup shades with 73% shade density for installation over the greenhouse to control the temperature.

2. Further Studies on Coal Fly Ash: The analysis of coal fly ash collected from various coal-fired plants at and near Savannah River Plant Facilities for possible metals and nonmetals have been completed and the results have been reported in our previous report. It was observed at the time of data analysis that SRS 484-D fly ash is relatively rich in Ca, but contains only smaller quantities of transition metals. It was thought that transition metals may have been bound very strongly with this very fine ash (particle size ( 500 um in diam.) so that these metals are not extracted significantly with water. To study the effect of particle size on the binding of transition metals with fly ash, samples from SRS 184-K plant which does not have an electrostatic precipitator were fractionated into three fractions using sieves of different pore size. Water extracts from the fractionated samples were analyzed for selected elements using the same procedure as reported earlier to determine whether particle size has any effect on the concentration of elements in water extracts.

3. Preparation of New Fly Ash-amended Composts using different Organic Composts: Two additional types of organic composts, "Compost Toast" commercially available from Bricker's farm (a low grade manure) and "Home-made Compost" (green grass composted outside the greenhouse for six weeks or more) were used to make fly ash-amended composts. A large quantity (22 kg) of fly ash-amended compost containing 20% fly ash (SRS 484-D) was prepared with "Compost Toast" in plastic containers to determine the optimum FA-amended compost/soil ratio for plant growth using corn as a represntative

for plant study. This compost as well as the origanic manure were allowed to decompose for two weeks. Water extracts from the composted manure and from fly ash-amended composts were analyzed for selected elements. Home-made compost, on the other hand, was mixed with the same fly ash in six different proportions (15%, 20%, 30%, 40%, 50% and 60% FA) and allowed to decompose for two weeks. Water extracts from the composted original manure and from the fly ash-amended cmposts were analyzed for selected elements as before.

4. Measurement of the Optimum FA-compost/soil Ratio using Corn Plant: Corn seeds were planted in pots containing various proportions of FA-amended compost and soil. The total weight of the matrix was 7 kg. After germination, when the plants grew to a height of about 3", they were thinned by pulling out all but three in each pot. The plants were watered regularly with the maga-pure water and at the end of eight weeks they were harwested by cutting the stem about one inch above the soil. The weights of the plants (wet weight) were measured immediately. They were then dried in the oven for 3-5 days at $70^{o}$ C. The weights of dry plants from each pot were also determined. The dry leaves were grinded and powdered in a motor-driven steel blender (Thomas Scientific Co.). A represntative 1 g-sample of the plants from each pot taken in a quartz crucible (30 ml) was incinerated in an electric furnace (Blue M. Electric Co.) to ashes. The ash was digested with 10 ml of 1 N HCl and the clear solution was diluted to 100 ml. This stock sample was used for the analysis of trace elements present in plant samples. The original sample was diluted by a factor of $10^2$ or $10^3$ to determine the concentration of major elements using atomic absorption or other techniques (Ref. 1)

5. Optimization of Fly ash/Compost Ratio for Plant growth using Home-made Compost: It is important that the right amount of fly ash is used to

prepare the fly ash-amended compost as manure for the maximum growth and yield of the plants. Organic compost was made at the site by laying 1 ft. layers of green grass one over the other in a heap (3'x3'x3') outside the greenhouse and springling water and initiator (rich manure or ammonim nitrate) over each layer. The system was allowed to decay for a period of 4 weeks or more with occassional turning over. This "home-made compost" was mixed with fly ash collected from SRS 484-D in various compositions as described before and allowed to decompose for two weeks. The original compost with no fly ash was also allowed to decompose for the same period. The total weight of each FA-compost mixture was about 10 kg. Water content of these composted samples were determined by dehydration method. Water extracts from each of these samples were also analyzed for selected major and minor elements as discussed in previous report.

Corn and Sorgum plants were chosen for this study. Four pots, each containing 1.75 kg of fly ash-amended compost of an assigned composition and 5.25 kg of silted soil mixed thoroughly with the twin-shell dry blender were used to sow the seeds of each plant. The FA-compost/soil ratio was kept constant at 0.333. Altogether there were 8 sets of pots for each plant including the controls with no compost. After sowing the seeds of the two plants, thinning the plants to three and processing of the plant samples after the harvest were done in the same way as before. Concentrations of selected major and minor elements were determined using techniques described in previous report.

6. Testing the Experimentally Determined Optimum Parameters for Plant Growth using Collard and Mustard Greens: Seeds of collard and mustard greens were planted in plastic pots (10.5"Wx10" H) as before during the Fall of 1989. Fly

ash-amended composts (0% FA, 15% FA, 20% FA, 30% FA, 40% FA, 50% FA and 60% FA) were prepared using home-made compost and fly ash collected from SRS 484-D. These fly ash-amended composts were mixed with soil in the ration 1:3 using the blender. A 7 kg-mixture with the required fly ash content was placed in the respective pot for sowing the seeds. The plants were grown, harvested and dried as discussed before. Although the weights of the wet and dry plants were determined the analysis of these plants has not been completed yet.

## RESULTS AND DISCUSSION

The results of the study on distribution of selected elements among fractions of SRS 184-K fly ash sample separated according to particle size are presented in Table I. In general, the fraction with particles greater than 500 um in diameter yielded highest concentrations of these elements in water extracts in conformity with the suggested mechanism of absorption and retention of elements by coal ash during coal burning process. These results and others from the analysis of coal fly ash samples have been reported in our paper accepted for publication (Ref: 2).

Results of the analysis of the collard and mustard greens raised during the Fall of 1988 which were not included in last years report are presented in Table II and Table III, respectively. Figure 1 is a bar plot of plant yield of both collard and mustard greens vs. percent of fly ash in the compost for a constant FA-amended compost/soil ratio of 0.014. It has been reported (Ref. 1) that "Gotta Grow", the organic manure used for this study, was very rich in nutrients and therfore, the effect of fly ash on FA-amended

compost was hardly visible. Besides, the FA-amended compost /soil ratio used for the study was only 0.014, a very small ratio for possible utiliztion of fly ash. For these reasons, the results of analysis of these plants may not bear any significance.

Results obtained from the analysis of corn plants grown to determine the optimum FA-amended compost/soil ratio are shown in Table IV. Figure 2 gives the bar plot of plant yield vs. percent of soil in the FA-amended compost - soil mixture. It can be seen from this figure that a 25% compost in the mixture gives the highest yield for the corn plant although the yield when no fly ash is used for the compost is slightly higher. It is to be pointed out that the organic manure used in this study is "Compost Toast" and not home-made compost.

Results of analyses of home-made compost and fly ash-amended composts are presented in Table V. It can be seen from this Table that K, Ca, Mg, P and probably N are enriched in the FA-amended compost with 20% FA than in any other FA-amended composts. Results of analyses of FA-amended composts with 20% FA using diferent organic composts are compared in Table VI. This Table reveals that, out of the three orgnic composts tested home-made compost is probably the best in terms of utiliztion of coal fly ash, because only this compost, when mixed with 20% FA, can provide additional quantities of Ca and Mg present in fly ash to the plants. Besides, boron which seems to be a detrimental element for plant growth is present, in this specimen, in smaller quantities than in others. The pH and conductivity of water extracts of this compost are also more favourable for plant growth.

The optimum composition of the FA-amended compost (20% FA) was established by determining the yield of two plants, corn and sorgum, grown

using different compositions of fly ash and home-made compost at constant FA-compost/soil ratio (0.333). Results of analyses of plants obtained from these experiments together with the plant yield are presented in Tables VII and VIII. Figure 3 depicts the bar plots of the weights of plants vs. percent of fly ash in compost for both of these plants. It is obvious from these Tables as well as from the figures that FA-amended compost with 20% FA when mixed with soil provides the plants with nutrients for maximum growth. In general, the uptake of some of the nutrient elements such as K, Ca, Mg, P and N in terms of ug/g of plant is also highest when the plant is nurished with 20% FA in the compost. It appears that the uptake of elements by the plant may also depend on the nature of the plant. A detailed analysis of the data from fly ash-amended composts and plants has not been completed yet. Therefore, the mechansim of interaction of fly ash with compost and the synergic and antagonistic effects of elements for uptake by plants could not be evaluated.

Collard and mustard greens were grown under the above experimental conditions to test the hypothesis arrived at from previous experiments. The analysis of plant samples has not been completed at this time. However, the plant yield data have been plotted against the composition of FA-amended composts in Figure 4. This Figure also shows that the maximum yield of the plant , in the case of both plants, was obtained when FA-amended compost with 20% FA is used.

Figure 5 gives a comparison of yield data for corn and sorgum with concentrations of K, Ca, B and N when plotted as a function of percent fly ash in FA-amended home-made compost. It is clear from this figure that the bioavailability of K, Ca and N is highest at 20% FA level, while that of

boron is low.

## CONCLUSION

Tentative conclusions reached from the second year study are the following:

1. Fractionation studies show that there are variations in the concentrations of elements in water extracts of fractions of SRS 184-K ash separated on the basis of particle size. In general fraction with particles greater than 500 um in diameter yielded highest concentration of these elements in water extract.
2. Out of three organic composts (two commercial and one home-made) used to make fly ash-amended composts home-made compost seems to be more efficient for effective utilization of fly ash.
3. A fly ash-amended home-made compost with 20% FA is recommended as manure for plant growth.
4. A uniform mixture containing 25% fly ash-amended compost (20% FA) and 75% silted soil will make the best bed for vegetation.
5. The maximum yield of the plant is corelated with the higher content of K, Ca, and N and lower content of B at 20% FA level of the compost.

## PROJECT PLAN FOR THE COMING YEAR

During the third year of the project which starts from June 1, 1990 the following studies will be undertaken to examine additional aspects of coal fly ash research:

1. Evaluation of the data obtained from the analysis of fly ash-amended composts and of plants.
2. Distribution profile of selected metals in SRS 484-D coal ash collected from different locations.
3. Vertical distribution profile of selected metals in crude coal and in coal ash collected from different hoppers in SRS 484-D Plant.
4. Downward transport of nutrients from fly ash-amended compost in columns filled with sand.
5. Application of the prescribed FA-amended home-made compost to other useful plants to evaluate its effectiveness.

## REFERENCES

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2. Physico-chemical Characteriztion of Water Extracts of Different Coal Fly Ashes and Fly Ash-Amended Composts. M.P. Menon, G.S. Ghuman, J. James, K. Chandra and D.C. Adriano, Water, Air and Soil Pollution (in Press)

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1. Physico-chemical Characterization of Water Extracts of Different Coal Fly Ashes and Fly Ash-amended Composts. M.P. Menon, G.S. Ghuman, J. James K. Chandra and D.C. Adriano, Water, Air and Soil Pollution (in press).

## STUDENT TRAINEES

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Table I

Distribution of Selected Elements among Fractionated SRS 184-K Fly Ash Samples*

| Measured quantity | Fraction (1) | Fraction (2) | Fraction (3) |
|---|---|---|---|
| size | 180 um | 500 um | 500 um |
| Percentage | 70.2 | 20.4 | 9.4 |
| Conductivity (umho) | 1609 + 2.8 | 1142 + 83 | 1438 + 35 |
| pH | 3.98 | 3.98 | 3.86 |
| | ppm | | |
| Na | 733.4 + 42# | 542.1 + 22 | 904.8 + 16.4 |
| K | 135.2 + 40.3 | 91.8 + 33.3 | 156.1 + 43.7 |
| Ca | 1715.0 + 212 | 517.0 + 58 | 411.0 + 100 |
| Mg | 291.0 + 29 | 244.0 + 6 | 352.0 + 8 |
| Zn | 28.4 + 0.4 | 25.2 + 0.7 | 36.2 + 1.7 |
| Mn | 46.6 + 0.7 | 44.2 + 1.6 | 67.6 + 3.9 |
| Cu | 0.6 + 0.3 | 3.1 + 0.5 | 4.5 + 2.6 |
| Ni | 12.7 + 0.5 | 9.7 + 0.5 | 18.5 + 2.1 |
| B | 66.2 + 2.8 | 76.8 + 5.0 | 76.9 + 4.3 |
| S | 3562.0 + 309 | 2960.0 + 375 | 3260.0 + 227 |

*: Equilibrated water extracts were analyzed

#: Average of 4 determinations

Table II

Results of the Analysis of Collard Greens grown in Silted Soil mixed with Fly Ash-Amended Organic Composts of different Compositions

| Elements & wt. of Plants | Control 0A-0D | 1A-1D 0% FA | 2A-2D 5% FA | 3A-3D 10% FA | 4A-4D 20% FA | 5A-5D 30% FA | 6A-6D 40% FA | 7A-7D 50% FA |
|---|---|---|---|---|---|---|---|---|
| | (Average of four replicate pot samples) | | | | | | | |
| | ppm | | | | | | | |
| K x $10^{-4}$ | | 11.4(1.4)* | 9.9(.7) | 13.2(1) | 11.4(.9) | 11.7(.5) | 11.8(.9) | 8.3(1.3) |
| Na x $10^{-4}$ | | 2.0(.1) | 2.1(.2) | 2.1(.4) | 2.1(.2) | 1.9(.1) | 1.8(.1) | 1.6(.1) |
| Ca x $10^{-4}$ | | 1.3(.3) | 1.9(.1) | 1.9(.4) | 1.9(.5) | 1.7(.7) | 1.2(.2) | 1.3(.2) |
| Mg | | 10.3(.4) | 10.4(.8) | 10.2(1.6) | 9.8(1.3) | 8.6(1.7) | 7.6(.6) | 7.2(.5) |
| Zn | | 332(57) | 436(58) | 376(62) | 400(45) | 438(33) | 390(46) | 382(77) |
| Mn | | 304(71) | 447(58) | 339(77) | 384(74) | 384(81) | 322(33) | 418(41) |
| Cu | | 58(16) | 4.7(0) | 30(13) | 23(10) | 20(3) | 14(7) | 30(16) |
| Ni | | | | 25(14) | 9.3(0) | 26(5) | 21(14) | 23(9) |
| B | | 65(5) | 86(15) | 85(5) | 88(12) | 61(12) | 64(2) | 63(6) |
| P x $10^{-4}$ | | 7.6(.6) | 4.2(.8) | 4.1(.7) | 4.2(.2) | 3.7(.3) | 3.5(.7) | 2.1(.3) |
| S x $10^{-4}$ | | 1.2(.09) | 1.5(.3) | 2.3(.4) | 2.3(.04) | 2.4(.4) | 2.1(.4) | 1.7(.05) |
| N x $10^{-4}$ | | 2.3(.6) | 2.0(.08) | 2.2(.2) | 3.0(.3) | 3.1(.1) | 1.5(.03) | 1.6(.04) |
| Yield per pot | | | | | | | | |
| (wet) g | 0.3(.1) | 41(40) | 126(29) | 166(13) | 117(41) | 130(29) | 90(45) | 46(19) |
| (Dry) g | 0 | 1.2(1.2) | 4.9(2) | 4.2(.2) | 2.9(1.1) | 3.4(.8) | 2.6(1.6) | 2.1(.8) |

* Numbers in the parenthesis are standard deviations from the average.

Table III

Results of the Analysis of Mustard Greens grown in Silted Soil mixed with Fly Ash-Amended Organic Composts of different Compositions

| Elements & wt. of plants | Control 0A-0D | 1A-1D 0% FA | 2A-2D 5% FA | 3A-3D 10% FA | 4A-4D 20% FA | 5A-5D 30% FA | 6A-6D 40% FA | 7A-7D 50% FA |
|---|---|---|---|---|---|---|---|---|
| | (Average of four replicate pot samples) | | | | | | | |
| | ppm | | | | | | | |
| K x $10^{-4}$ | | 14.9(1.5)* | 10.7(1.1) | 14.9(1.9) | 18.0(1.5) | 13.8(2.0) | 13.3(3.2) | 7.4(1.8) |
| Na x $10^{-4}$ | | 2.3(.3) | 1.9(.2) | 1.4(.3) | 1.6(.4) | 1.4(.3) | 1.8(.5) | 1.7(.4) |
| Ca x $10^{-4}$ | | 1.0(.1) | 1.1(.1) | 1.2(.2) | 1.1(.2) | 1.2(.1) | 1.2(.1) | 1.4(.2) |
| Mg x $10^{-4}$ | | 5.4(1.0) | 5.5(.4) | 5.9(.8) | 4.7(1.0) | 4.6(.7) | 4.8(.1) | 5.3(.6) |
| Zn | | 320(55) | 315(48) | 300(27) | 324(48) | 329(14) | 373(66) | 429(57) |
| Mn | | 127(17) | 192(44) | 205(27) | 258(70) | 224(41) | 212(34) | 371(33) |
| Cu | | 15(2) | 21(10) | 28(0) | 12(3) | 33(0) | 16(3) | 34(10) |
| Ni | | 19(11) | 9(0) | 16(9) | 13(5) | 14(16) | 12(23) | 16(14) |
| B | | 46(2) | 44(8) | 48(10) | 46(2) | 55(10) | 71(6) | 71(6) |
| P x $10^{-4}$ | | 3.7(.9) | 4.0(.8) | 5.0(.6) | 4.1(.5) | 5.2(.8) | 5.7(.7) | 3.0(.7) |
| S x $10^{-3}$ | | 7.9(.9) | 8.6(1.2) | 9.6(1.7) | 9.2(2.2) | 9.2(.9) | 12(1.2) | 10.2(1.9) |
| N x $10^{-4}$ | | 1.3(.1) | 1.2(.03) | 1.1(.07) | 1.0(.07) | 1.2(.1) | 1.1(.1) | 1.1(.2) |
| yield per pot | | | | | | | | |
| (wet) g | 3.4(1.5) | 172(114) | 306(38) | 173(100) | 75(70) | 157(80) | 180(35) | 239(54) |
| (dry) g | .04(.04) | 5.8(.3) | 8(2.8) | 4.7(2.7) | 2.5(2.2) | 7.1(5.7) | 5.5(1.8) | 5.9(1.7) |

* Numbers in the parenthesid are standard deviations from the average.

Table IV

Results of Analysis of Corn Plant grown in Silted Soil mixed with Fly Ash-Amended "Compost Toast"(20% FA) under different Soil/Compost Ratio#

| Element & Wt. of Plants | Control 0A-0D Soil | 1A-1D 85:15 No FA | 2A-2D 98:2 | 3A-3D 95:5 | 4A-4D 90:10 | 5A-5D 85:15 | 6A-6D 80:20 | 7A-7D 75:20 |
|---|---|---|---|---|---|---|---|---|
| | | (Average of four replicate pot samples, ppm) | | | | | | |
| K | 9631 | 13004 | 5575 | 7700 | 7638 | 9538 | 11775 | 13562 |
| Na | 26187 | 29813 | 18188 | 28250 | 32969 | 42219 | 32750 | 38812 |
| Ca | 8844 | 4156 | 6792 | 5406 | 5965 | 4788 | 4044 | 3788 |
| Mg | 5853 | 4353 | 6123 | 5894 | 5138 | 4395 | 3741 | 3704 |
| Zn | 47(11)* | 43(5) | 38(9) | 37(3) | 40(6) | 44(6) | 41(6) | 31(2) |
| Mn | 51(9) | 27(5) | 36(1) | 32(2) | 29(3) | 33(5) | 33(4) | 33(2) |
| Cu | 4.2(.8) | 3.5(.4) | 4(.7) | 4.2(.8) | 3.3(0) | 3.3(0) | 3.8(.4) | 3.8(3) |
| Ni | 2.7(1.6) | 4.7(2) | 3.7(1.6) | 4.1(3.5) | 0.8(.1) | 4.6(1.4) | 1.0(.6) | 4.2(1.) |
| S | 10375 | 7729 | 10990 | 7271 | 8417 | 10031 | 8221 | 10875 |
| N | 915(63) | 1219 | 1259 | 845(45) | 949(203) | 1262 | 1347 | 1324 |
| Yield per pot | | | | | | | | |
| (wet) g | 0.3(.1) | 41(40) | 126(29) | 166(13) | 117(41) | 130(29) | 90(45) | 46(19) |
| (Dry) g | 0 | 7.0(1.1) | 10.2(2) | 13.5(2) | 9.9(3) | 1.1(3) | 8.6(4.4) | 4.6(1) |

*: Numbers in parethesis are standard deviations from the mean.

#: "Compost Toast" was purchased from Bricker Farm, Augusta, GA.

Table V

Results of Analysis of Home-made Compost and Coal Fly Ash Amended Compost*

| Element | Comp.(1) 0% FA | Comp.(2) 15% FA | Comp.(3) 20% FA | Comp.(4) 30% FA | Comp.(5) 40% FA | Comp.(6) 50% FA | Comp.(7) 60% FA |
|---|---|---|---|---|---|---|---|
| | ppm in dry compost | | | | | | |
| K | 3197(668)# | 2575(693) | 2952(63) | 2059(95) | 1501(71) | 1501(161) | 1189(59) |
| Na | 2199(209) | 1162(337) | 1404(406) | 1586(392) | 1299(272) | 852(157) | 2033(144) |
| Ca | 294(81) | 274(37) | 544(60) | 343(4) | 347(27) | 363(13) | 528(77) |
| Mg | 175(32) | 159(13) | 385(34) | 187(4) | 155(17) | 163(8) | 157(4) |
| Zn | 2.6(0.4) | 1.9(1.0) | 1.3(.3) | 0.7(.1) | 0.6(.1) | 0.5(.3) | 0.2(.1) |
| B | 23.3(4.3) | 29.1(3.7) | 18.1(5.2) | 32.4(5.8) | 30.9(6.3) | 40.3(8.1) | 41.5(2.1) |
| P | 560(27) | 269(42) | 367(108) | 133(4) | 69(14) | 73(15) | 24(5) |
| S | 4951(109) | 3986(71) | 4308(330) | 4044(176) | 3469(99) | 3760(101) | 3292(89) |
| N | 893(63) | 913(70) | 1320(109) | 761(136) | 1238(50) | 1624(169) | 1077(47) |

*: Home-made organic compost was prepared by heaping green grass layer after layer in a 3'x3'x3' stock, by occassional springling of water and turning over for decay.

#: numbers in parenthesis are standard deviation from the mean of four measuements

Table VI

Comparison of the Elemental Analysis of different Organic Composts amended with 20% Fly Ash

| Ele-ment | Gotta Grow (rich,commercial) | | Compost Toast (low grade, commercial) | | Home-made compost (Useful, economic) | |
|---|---|---|---|---|---|---|
| | 0% FA | 20% FA | 0% FA | 20% FA | 0% FA | 20% FA |
| | ppm of dry sample | | | | | |
| K | 23,026 | 22,709 | 783(45)* | 657(32) | 3197 | 2952 |
| Na | 8,670 | 4,941 | 1,376 | 790(21) | 2199 | 1404 |
| Ca | 1,352 | 1,915 | 411(37) | 149(11) | 294(81) | 544(60) |
| Mg | 436(103) | 228(27) | 67(6) | 42(3) | 175(32) | 385(34) |
| Zn | 69(7) | 53(2) | 3.7(.3) | 0.53(.1) | 2.6(.4) | 1.3(.3) |
| Mn | 6.2(3.1) | 8.2(1.6) | 6.1(.6) | 2.3(.5) | ---- | |
| Cu | 17(3) | 14(1) | 2.9(.6) | 3.1(.9) | ---- | |
| B | 80(5) | 33(6) | 9.8(3.9) | 29.7(4.9) | 23.3(4.3) | 18.1(5.2) |
| P | 316(21) | 324(11) | 2409(109) | 2041(81) | 560(27) | 367(108) |
| S | 2550(22) | 2185(52) | ---- | ---- | 4951(109) | 4308(330) |
| N | 939(109) | 692(49) | ---- | ---- | 893(63) | 1320(109) |
| pH | 8.5(.1) | 8.1(.1) | 7.0(.1) | 7.2(.1) | 7.6(.1) | 7.2(.2) |
| Conduct(umho) | 9050 | 5350 | 573(34) | 402(16) | 419(75) | 591(39) |

*: Numbers in parenthesis show standard deviation from the mean of four determinations

Table VII

Results of the Analysis of Corn Plants in Silted Soil mixed with Fly Ash-Amended Home-made compost of different compositions

| Element & Wt. of Plants | 0A-0D Con-trol | 1A-1D 0% FA | 2A-2D 15% FA | 3A-3D 20% FA | 4A-4D 30% FA | 5A-5D 40% FA | 6A-6D 50% FA | 7A-7D 60% FA |
|---|---|---|---|---|---|---|---|---|
| | (Average of four replicate pot samples; ppm) | | | | | | | |
| Kx $10^{-4}$ | 1.1(.4)* | 4.5(.5) | 4.4(.5) | 3.8(.3) | 3.1(.4) | 3.3(.5) | 3.6(.1) | 3.4(.4) |
| Nax $10^{-3}$ | 3.8(1.7) | 7.1(1.3) | 2.7(.6) | 3.1(1.1) | 3.3(1.4) | 5.2(2.0) | 2.8(.8) | 3.9(.6) |
| Cax $10^{-4}$ | 1.2(3.3) | .80(1.0) | .78(.1) | 1.0(2.2) | .92(.12) | .99(.15) | .95(.3) | .95(.1) |
| Mgx $10^{-4}$ | 1.1(.31) | .38(.15) | .31(.1) | .41(.1) | .33(.03) | .51(.04) | .27(.1) | .27(.1) |
| Zn | 33.3(7) | 27(5.1) | 30.8(6) | 18.9(2) | 22.8(7) | 37.3(8) | 24.7(3) | 19.5(7) |
| Mn | 51.2(14) | 10.7(2) | 16.4(2) | 11.1(2) | 18.0(4) | 12.9(4) | 11.0(3) | 26.4(5) |
| Cu | 11.8(1) | 10.4(.7) | 9.5(2) | 8.9(2) | 7.9(1) | 7.5(1) | 6.1(.7) | 6.8(1) |
| B | 25.6(6) | 38.3(4) | 30.1(7) | 45.6(5) | 74.6(11) | 73.7(9) | 54.5(4) | 85.8(17) |
| Px $10^{-4}$ | 12.4(5) | 30.0(7) | 40.0(1) | 23.9(3) | 23.2(3) | 21.6(5) | 26.3(5) | 16.8(2) |
| Sx $10^{-3}$ | 5.3(1.9) | 9.5(.3) | 9.3(.3) | 9.0(.3 | 9.3(1.1) | 8.9(.4) | 7.7(1) | 6.8(.6) |
| Nx $10^{-3}$ | 6.2(.4) | 5.9(1.1) | 2.3(.7) | 5.4(.5) | 4.5(1.1) | 3.7(.1) | 3.6(.2) | 4.4(.4) |
| Yield per pot | | | | | | | | |
| (wet) g# | 0.033 | 0.184 | --- | 0.232 | 0.197 | 0.158 | 0.126 | 0.099 |
| (dry) g | 0.030 | 0.172 | --- | 0.206 | 0.195 | 0.147 | 0.134 | 0.124 |

*: Numbers in parenthesis are standard deviation; #: Average of three pots

Table VIII

Results of the Analysis of Sorgum Plants in Silted Soil mixed with Fly Ash-Amended Home-made Compost of Different Compositions

| Element & Wt. of Plants | OA-AD Control | 1A-1D 0% FA | 2A-2D 15% FA | 3A-3D 20% FA | 4A-4D 30% FA | 5A-5D 40% FA | 6A-6D 50% FA | 7A-7D 60% FA |
|---|---|---|---|---|---|---|---|---|
| | (Average of four replicate samples; ppm) | | | | | | | |
| Kx $10^{-4}$ | 1.2(.1)* | 4.0(.4) | 4.1(.6) | 4.6(.3) | 3.8(.7) | 4.0(.3) | 3.8(.3) | 3.4(.1) |
| Nax $10^{-3}$ | 1.4(.3) | 1.1(.02) | 2.3(.1) | 4.6(2.7) | 2.6(1.4) | 1.7(.4) | .9(.2) | 2.2(.7) |
| Cax $10^{-3}$ | 11.1(1) | 6.7(.1) | 8.0(2.5) | 7.0(1) | 9.5(2.5) | 8.7(.6) | 7.2(.3) | 10(1.7) |
| Mgx $10^{-3}$ | 7.4(1.5) | 4.7(1.7) | 5.0(1.6) | 5.5(.2) | 7.3(.4) | 6.3(.6) | 4.9(.1) | 6.7(.9) |
| Zn | 14.1(1) | 19.4(3) | 19.2(4) | 26.9(4) | 19.3(5) | 20.4(2) | 17.9(4) | 18.5(2) |
| Mn | 37.9(3) | 25.3(5) | 26.6(6) | 22.8(4) | 28.2(3) | 28.3(3) | 32.0(2) | 26.0(3) |
| Cu | 9.7(1) | 9.7(1) | 8.2(1) | 7.6(1) | 11.1(2) | 9.7(1) | 11.4(3) | 10.3(2) |
| B | 23.7(10) | 17.4(2) | 18.5(5) | 17.1(2) | 21.1(4) | 26.9(5) | 18.7(17) | 61(22) |
| Px $10^{-4}$ | 17.8(1) | 41.9(2) | 40.0(7) | 41.0(5) | 31.6(5) | 38.1(4) | 31.9(4) | 26.4(7) |
| Sx $10^{-3}$ | 6.2(1) | 8.0(.4) | 6.8(.4) | 7.3(1.5) | 6.1(2.3) | 5.4(.8) | 6.0(2.5) | 6.0(1) |
| Nx $10^{-3}$ | 2.0(.1) | 2.7(.1) | 2.2(.5) | 1.9(.1) | 2.0(.1) | 1.9(.1) | 2.0(.2) | 1.9(.1) |
| Yield per pot | | | | | | | | |
| (wet) g# | 0.107 | 0.273 | 0.281 | 0.313 | 0.273 | 0.292 | 0.225 | 0.244 |
| (dry) g | 0.016 | 0.027 | 0.030 | 0.031 | 0.033 | 0.032 | 0.024 | 0.027 |

*: Numbers in parenthesis are standard deviations; #: Average of three pots

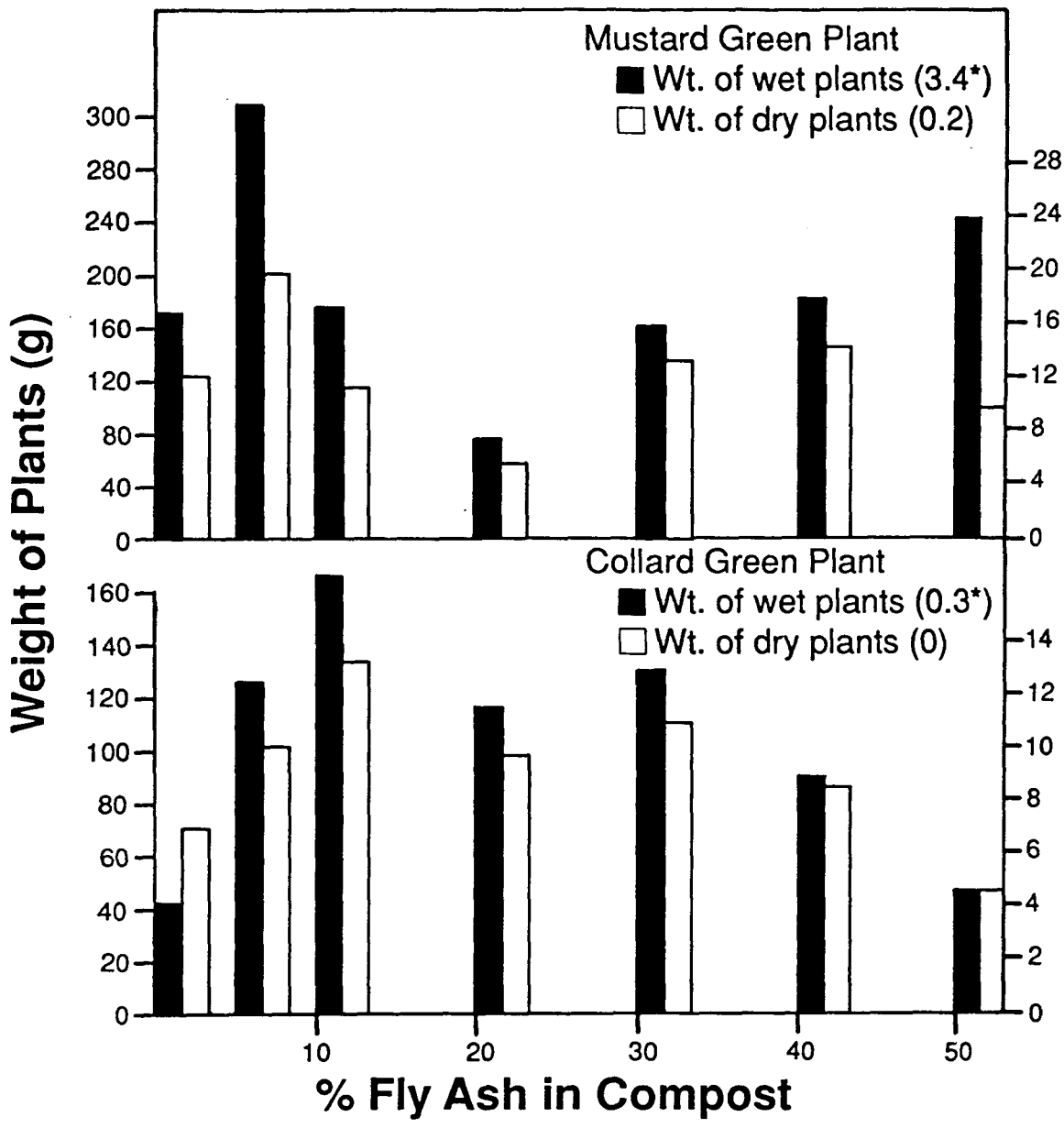



Figure 1. A bar plot of yield of the plant as a function of percent fly ash in fly ash-amended compost (Collard and mustard greens grown in winter,1988)

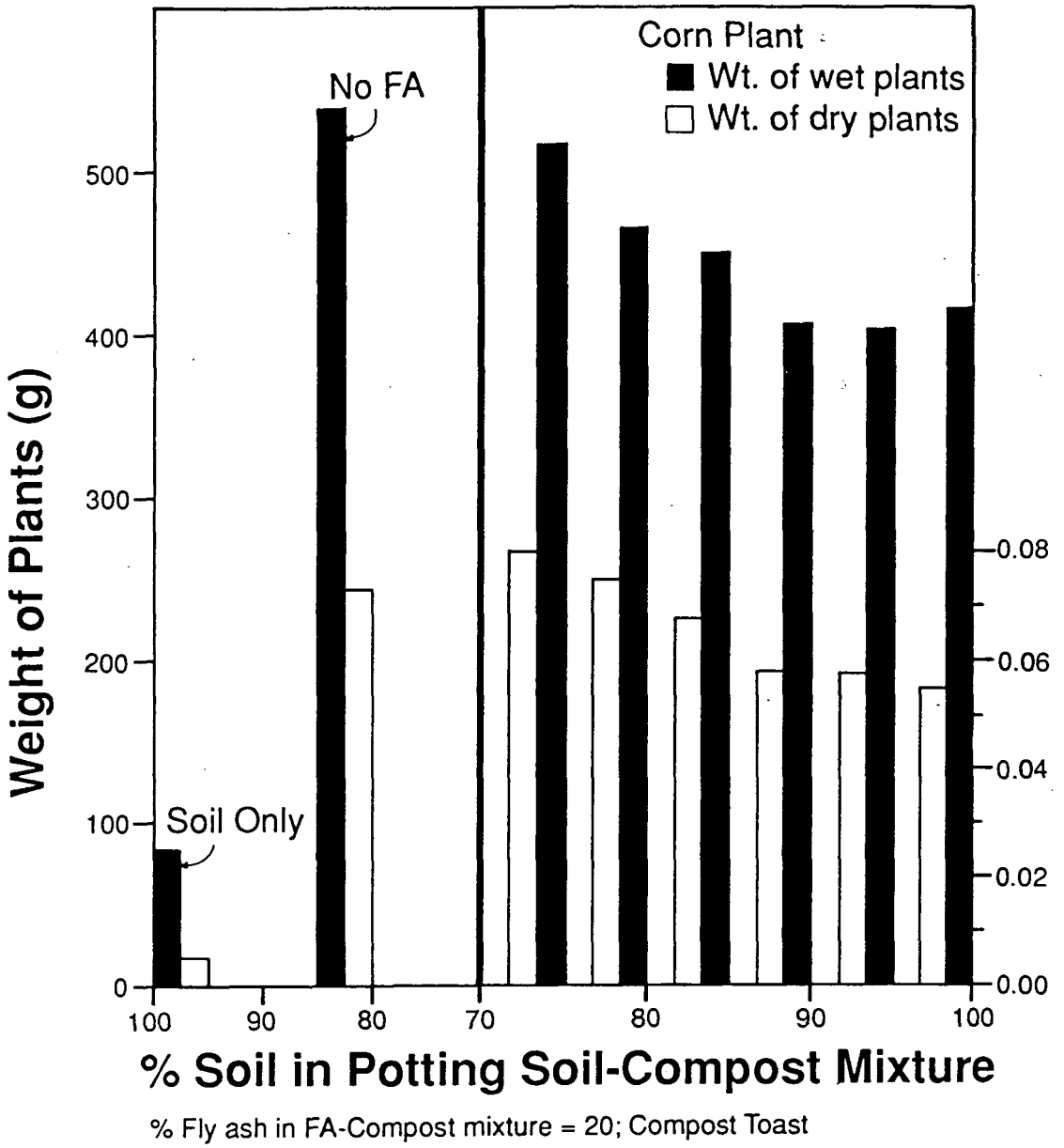
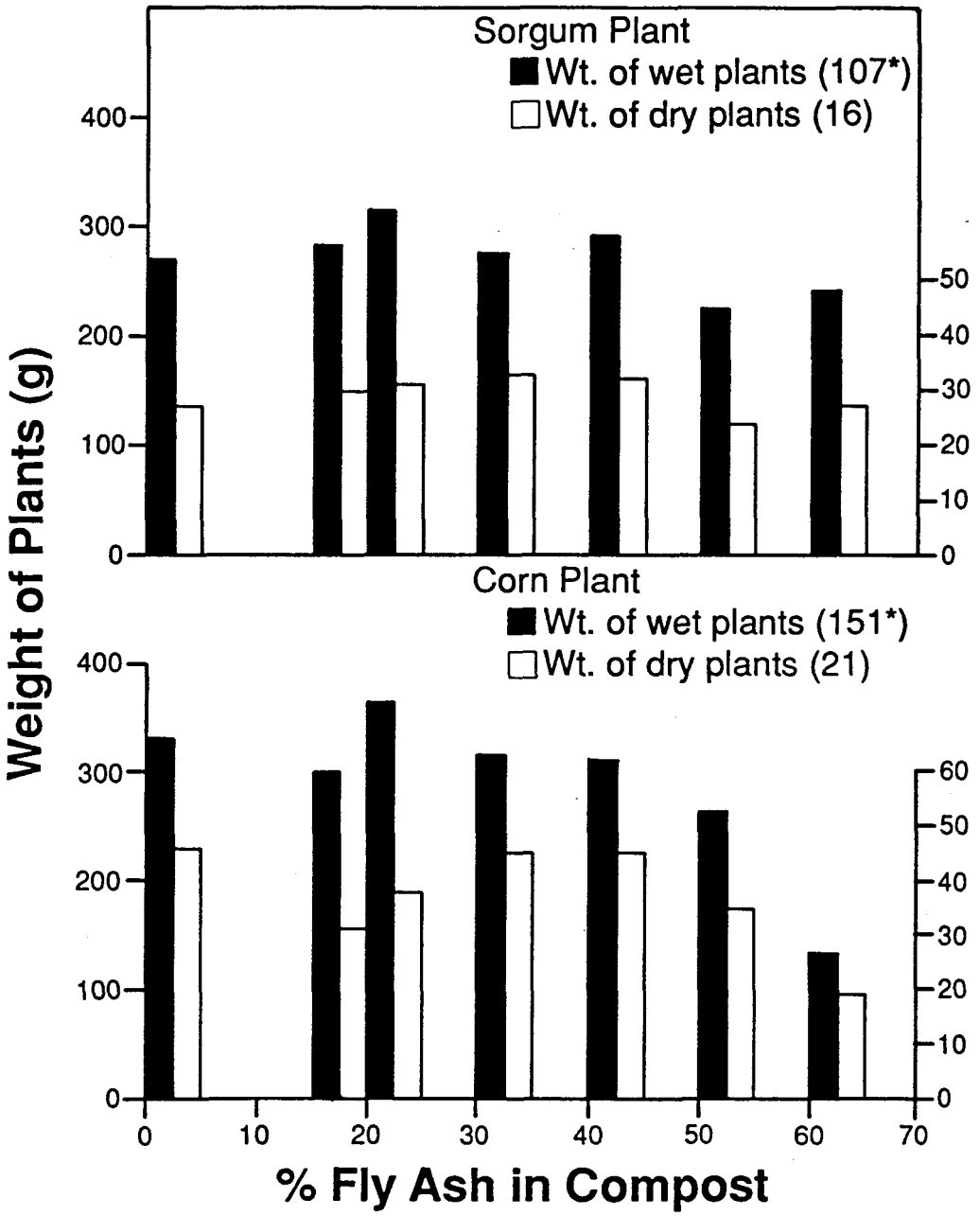
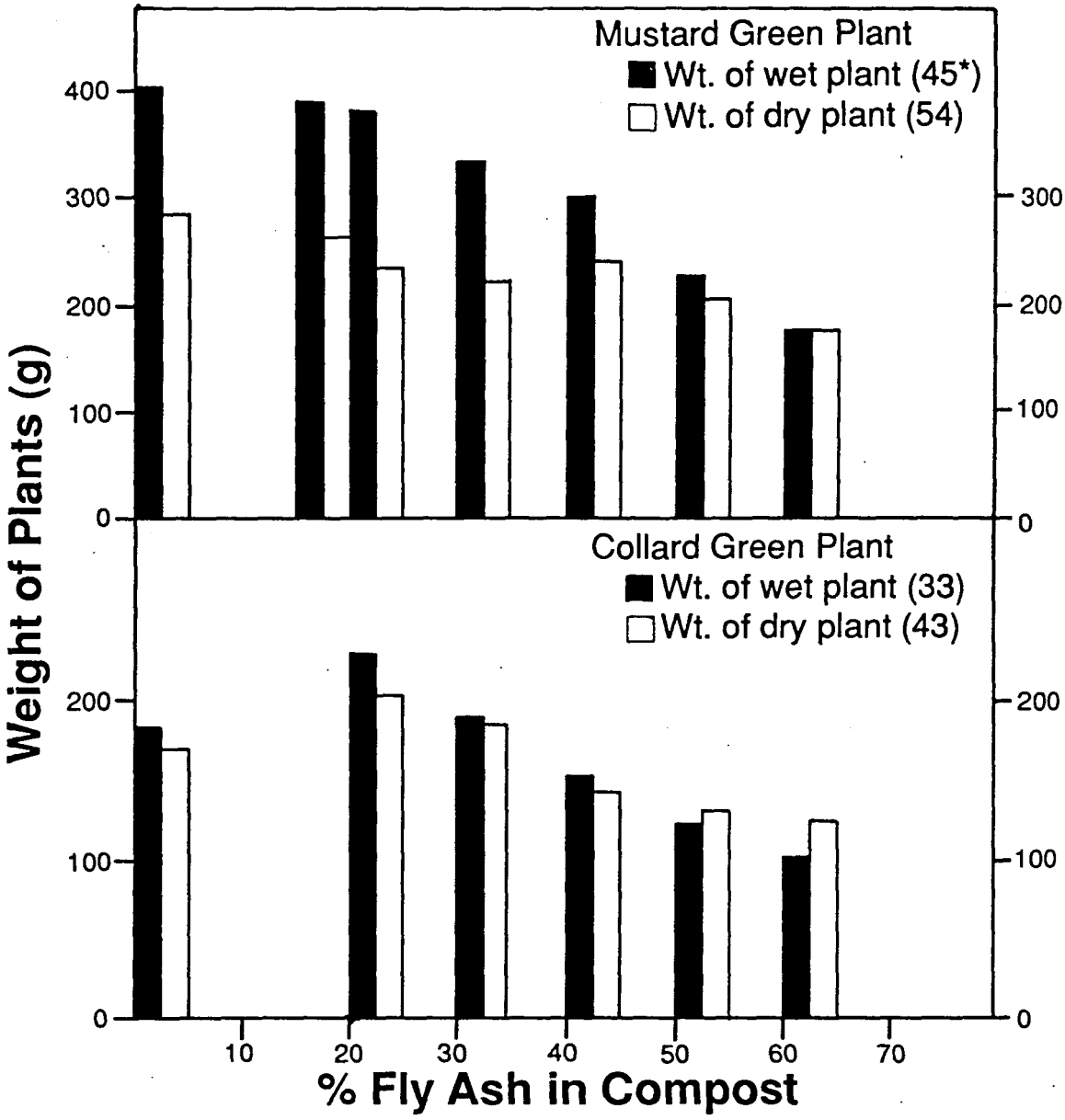



Figure 2. A bar plot of the yield of corn plant vs. percent of soil in potting soil-compost mixture




FA-Compost/Soil Ratio = 0.333; *Control; Home -made compost

Figure 3. A bar plot of the yield of the plant vs. percent of fly ash in fly ash-amended compost (Corn and Sorgum planted in Spring, 1989)




FA-Compost/Soil Ratio = 0.333; * Control; Home -made compost

Figure 4. A bar plot of the yield of the plant as a function of percent of fly ash in fly ash-amended compost (collard and mustard greens grown in winter, 1990)

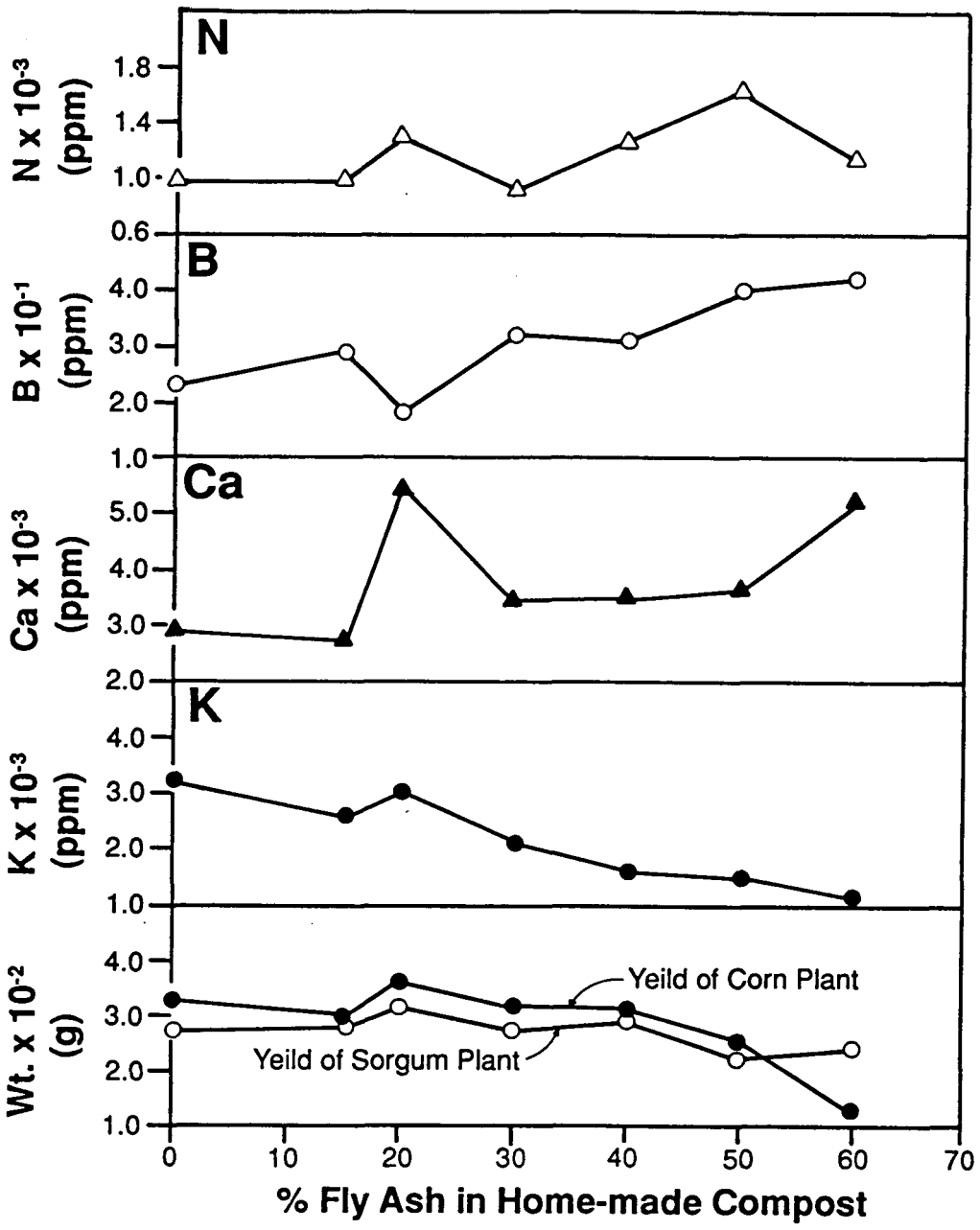



Figure 5. Comparison of plant yield with concentrations of selected beneficial and detrimental elments in plants plotted as a function of percent fly ash in compost