*J. Agric. Sci. Mansoura Univ., 29 (3): 1433 - 1455, 2004*

# EFFECTS OF SPRAYING WITH POTASSIUM AND FUNGICIDES ON THE CONTROL OF EARLY BLIGHT DISEASE AS WELL AS POTATO YIELD AND QUALITY

**Ismail[1], A.A., E. A. Radwan[2] and M. A. Elhaak[3]**
**1- Plant Pathology Res. Ins.**
**2- Horticultural Res. Ins., Agric. Res. Center, Giza**
**3- Botany Dept. Fac. Sci. Tanta Uni. Tanta, Egypt**

## ABSTRACT

The present study was carried out at Gemmeiza Agricultural Research Station at El-Gharbiya Governorate, Egypt in two successive growing seasons of potato (*Solanum tuberosum*, cv Diamant) as a host plant for *Alternaria solani* causing the early blight disease. The study included a laboratory and field experiments. *In vitro* results showed that Champion was the most potent as it had $IC_{50}$ of 0.37ppm while Koruse had the least effect ($IC_{50}$ value of 5.65ppm). Potassium had a negligible toxic effect in comparison with the used fungicides where its $IC_{50}$ was 20.98ppm. The co-toxicity factor (CTF) indicated that K combinations with the used fungicides acquired synergistic or additive effects towards the fungus. The severity of early blight disease in potato plants under the field conditions decreased greatly by the doses than the half doses of the used fungicides. Combining K with the fungicides reduced the disease severity especially with the doses of fungicides. Application of K combined with the tested fungicides caused marked increase in potato tubers yield as compared with the control. This may be due to the reduction of early blight disease incidence as indicated from the disease severity. In addition, the enhancement for vegetative growth was reflected greatly on the tubers crop of the plant. Potassium increased the fungicides half doses actual effectiveness to be equal or higher than that of their doses. Commercially, K combination with the used fungicides could be used to decrease both controlling costs of the disease and environmental pollution. The study recommends a potassium foliar spray at the time of fungicides application for increasing their effectiveness on the disease control and on the host plant growth and yield.

**Keywords:** Fungicides, Potassium, Early blight, Potato, Actual fungicide effectiveness (AFE).

## INTRODUCTION

The increase in world population increases the need for magnifying the productivity of crops or at least save crops from damage caused by microorganisms. Unfortunately, fungicides for plant protection are faced with changing nature of the diseases causal organisms. In addition, the accumulation of potent compounds to the pollution level from their continuous use has resulted in several environmental problems, especially if they have long persistence period (Beye, 1978). Pollution effects (Dubey and Mall, 1972) especially carcinogenic effect (Epstein, *et al.*, 1967) are mainly a result of accumulation of these compounds in the edible parts of crops (Ames and Gold, 1997). However, reduction of introduced fungicides and pesticides amounts in the environment became an international target (Moustafa and Ismial, 2003).

*Alternaria solani* caused early blight disease, a very destructive disease, for the important potato food crop in many regions of the world as in Egypt. In Egypt 19 fungicides belonging to different chemical groups are recommended for the control of this disease (Annon, 2001). Optimization of the used fungicides includes reducing their side effects on the sprayed plants through studying the best time of application and the effective concentration under the prevailing environmental conditions. On the other hand, increasing of the host plant defense against fungal infection is an important goal for decreasing the use of fungicides, at least, their concentrations. Of these, potassium spraying that reduces disease incidence through its effect on host-pathogen-interaction (Habibullah and Prasad, 1976 and Bwruah and Saikia, 1989). Potassium changes phenolics carbohydrate and nitrogenous substances in the host plants (Ramasamy, 1974) and inhibits enzymes as pectinolytic and cellulolytic (Sivaprakasam 1994), toxins and other secondary metabolites produced by the pathogen (Alagapan, 1976 and Anthonic, 1977). It reduces also infection for plant by disease through its acceleration for lignification of sclerenchymatous cells or increasing the thickness of cell wall. On the other hand, K is an important nutrient element that affects crops production ( Abo-Sedra and Shehata, 1994).

This work aims to study the effect of some fungicides in the control of early blight disease of potato at half or recommended dose as single or combined with 3% $K_2SO_4$ (K) in the laboratory or in the field. The effect of these treatments on vegetative growth and crop yield of potato plants was also included.

## MATERIALS AND METHODS

The present research was carried out at Gemmeiza Agricultural Research Station at El-Gharbiya Governorate, Egypt in two successive growing seasons of potato plants (2001 and 2002). Potato tubers (*Solanum tuberosum*, cv Diamant) were used as the host plant for *Alternaria solani* causing the early blight disease. *A. solani* was isolated, purified and identified at the Pathology Research Institute, A.R.C., Giza, Egypt. The test chemical compounds as fungicides are copper oxides and hydroxides or non-copper and they are described in Table (1). The fungicides were used alone or combined with foliar spraying by 3%$K_2SO_4$ (K).

**Table (1): The used chemical compounds in the present study.**

| Trade name | Common name | Recomanded dose | Formulation | Code in text |
|---|---|---|---|---|
| Acrobat/Copper46% | Dimethomorph + copper oxychloride | 250g/100 liter | W.P. | Acrobat |
| Galbin/Copper46% | Benaloxyl + copper oxychloride | 250g/100 liter | W.P. | Galbin |
| Chambion77% | copper hydroxide | 250g/100 liter | W.P. | Chambion |
| Ridomil Plus | Metalokyl + copper hydroxyl | 150g/100 liter | W.P. | Ridomil |
| Equation Pro52.5% | famoxadone + cymoxanil | 40g/100 liter | W.G. | Equation |
| Koruse50% | Cyprodinil | 50g/100 liter | W.G. | Koruse |
| Potassium salt | K2SO4 | 3% | Salt | K |

**W .P = wettable powder , W.G = water dispersible granules**

**Laboratory experiment:**

A laboratory experiment was performed to examine the sensitivity of *A. solani* for increasing concentrations of the used fungicides and K. The required concentrations of the fungicides (0.1 to 50 ppm) and K (10 to 100 ppm of $K_2SO_4$) were prepared from stock suspensions or solutions and added to 100 ml portions of autoclaved potato dextrose agar (PDA) medium cooled to about 50 °C. A non-amended control was also prepared. Approximately 20 ml PDA amended with the different treatments PDA were poured into five Petri dishes (10 cm in diameter). After solidification of the medium of each dish was inoculated centrally with a mycelial disc (5 mm in diameter) taken from the margin of actively growing PDA culture of *A. solani*. Then dishes were incubated at 30±2 °C in an incubator. Colony diameters were measured at the time when the untreated control had just covered the plate. Percentage of fungal growth inhibition was calculated according to a formula suggested by Topps and Wain (1957) and the concentration that led to 50% inhibition ($IC_{50}$) for each fungicide treatments was calculated according to Finney (1971). The $IC_{25}$ of each fungicide combined with $IC_{25}$ of K were used for the calculation of the fungicide Co-toxicity factor (CTF) by using the equation of Mansour *et al.* (1966) as follows:

$$\textbf{CTF} = [(\textbf{Obs. I\%} - \textbf{Exp. I\%})/\textbf{Exp. I\%}] \times 100$$

where: Obs. I% is observed inhibition % and Exp. I% is the expected inhibition %. According to this factor: the CTF more than 20 is a synergistic effect, the CTF less than -20 is an antagonistic effect, and the CTF between -20 and 20 is an additive effect for the combination of the fungicides with K.

**Field experiment:**

Potato tubers were planted on January 18$^{th}$ and 20$^{th}$ in 2001 and 2002 seasons , respectively in 18 m$^2$ plots, which were arranged according to split plot design. Each experimental plot area is 18m2 consisted of 4 rows 6 m long and 0.75 m width and their soil characteristics are presented in Table (2). The germinated plants were irrigated and fertilized according to the recommended system for the plant. At the vegetative stage the potato plants were subjected to spraying by the recommended dose and half dose of the used fungicides at 60 and 75 day after planting (DAP) at the two seasons, respectively. Water or 3% $K_2SO_4$ were sprayed on the plant foliage leaves in combination with the applied fungicides. The fungicides and K treatments were sprayed three times with 15 days intervals during the plant growth season.

Disease examination was carried out at the 60, 75 and 90 day of planting. Potato leaves were randomizely collected from each sub plot, the infection on each leaf was rated using the following index:

| **Numerical value ( Infection category)** | **Infection** |
|---|---|
| 0 | No infection spots in the leaf |
| 1 | Very small infection spots occupy less |

| | |
|---|---|
| | than 1/ 10 of the leaf area |
| 2 | Infection spots cover >1/4 of the leaf area |
| 3 | Infection spots cover >1/4 and < 1/2 of the leaf area |
| 4 | Infection spots >1/2 of the leaf area , or the leaf is destroyed. |

Disease severity was calculated using the equation developed by Towsend and Heubereger ,(1943) .

$$P = \frac{\sum(n \times v)}{4\,N} \times 100$$

where :

P = disease severity.
n= number of leaves within infection category .
v = numerical value of each leaves .
N = total number of leaves .

Fungicides effectiveness (FE) was calculated by the Abbott equation adopted by Fr.hlich (1979).

$$FE = \frac{C - T}{C} * 100$$

where :

C = disease severity in control.
T = disease severity in treatment.

Five days before harvesting, 5 plants from each plot were randomly harvested for the determination of number of main stems/plant, branches/stem and number and total leaves weight/plant. Then the leafing capacity and specific leaf weight were calculated according to the following equations:

**Leafing capacity (LC) = (Number of leaves/plant)(Number of branchs/plant).**

**Specific leaf weight (SLW) = (Total leaves dry weight/plant)/(Number of leaves/plant).**

Leaf samples were extracted by 2.5% aqueous N,N-dimethyl formamide for the determination of the photosynthetic pigments (Chlorophyll a and b) according to Moran and Portath (1980). The rest of plant shoots were dried to determine plant leaves dry weight and their contents of N, P and K which were extracted and determined according to Allen *et al.* (1979). After harvesting number and total weight of tubers per plant, percentage of dry matter content of tuber and tuber specific gravity were determined. The specific yield was calculated according to the following equation:

**Specific yield (SY) = (Tuber weight/plant)/(Leaves weight/plat)**

The actual fungicide effectiveness (AFE) was calculated according to Elhaak and Ismail (2003), but change in tuber biomass (CB) was used instead of the change in plant biomass as the following equations:

$$\% \text{ Change in tuber biomass (CB)} = \frac{\text{(sprayed plant tuber biomass - control plant tuber biomass}}{\text{control plant tuber biomass}}$$

% Actual fungicide effectiveness (AFE) = (FE + CB)

Then the tuber content of starch was analyzed according to Nagiub (1963), while the content of each N, P and K was analyzed as previously mentioned.

The obtained results were analyzed statistically by applying ANOVA and LSD according to Snedecor and Cochran (1973).

**Table (2) : The physical and chemical characteristics of the used soil in the present study .**

| Analysis | 2001 | 2002 |
|---|---|---|
| Soil is clay loam | | |
| Organic matter % | 1.20 | 1.10 |
| Soil solution pH | 8.20 | 8.10 |
| Soil solution EC at °C ( mmhos / cm ) | 0.80 | 0.85 |
| Spluble anion in soil saturated extract ( meq / 100 g D. soil ) | | |
| $CO_3^-$ | 0.00 | 0.00 |
| $HCO_3^-$ | 2.10 | 2.20 |
| $Cl^-$ | 4.80 | 4.60 |
| $SO_4^-$ | 1.80 | 3.00 |
| Nitrogen ( mg /100 gD.soil ): | | |
| Total | 202.50 | 230.50 |
| Available | 34.00 | 38.00 |
| Phosphorus (mg/100 gD.soil): | | |
| Total | 29.30 | 35.50 |
| Available | 5.90 | 8.20 |
| Potssium ( mg / 100gD.soil ): | | |
| Total | 480.00 | 530.00 |
| Available | 166.0 | 148.00 |
| Soluble cations in soil saturated extract (meq/100gD.soil) | | |
| $Na^+$ | 4.20 | 4.80 |
| $K^+$ | 0.30 | 0.40 |
| $Ca^{++}$ | 2.30 | 2.30 |
| $Mg^{++}$ | 1.90 | 2.30 |

## RESULTS

**Laboratory experiment:**

The growth of *Alternaria solani* was affected greatly by the addition of the used fungicides in its growth medium (Table 3). Champion was the most potent compounds against the fungal growth followed by Equation where they inhibited its growth by 50% ($IC_{50}$) at low concentrations (0.37 and 0.95ppm respectively). Koruse gave the least toxic effect with an $IC_{50}$ value of 5.65ppm, it has also a wide confidence limit for application. On the other hand, addition of the different concentrations, of $K_2S0_4$ (K) to the fungal growth medium had a negligible toxic effect in compaired with the used fungicides where its $IC_{50}$ is 20.98ppm.

**Table (3): Ic50 values , percentage of inhibition ( I % ) , and Co. Toxicity Factor ( C.T.F) of K combined with tested fungicides against *A. solani* ( Ic25 for each )**

| Fungicides & $K_2SO_4$ | IC50 | Fungicides+ K | I% | CTF | Effect |
|---|---|---|---|---|---|
| Acrobat | 1.32 | Acrobat + K | 68.05 | + 36.10 | Synergistic |
| Galbin | 0.95 | Galbin + K | 48.61 | - 2.78 | Additive |
| Chambion | 0.37 | Chambion + K | 69.44 | + 38.88 | Synergistic |
| Ridomil | 1.80 | Ridomil + K | 51.38 | + 2.76 | Additive |
| Equation | 0.78 | Equation + K | 72.22 | + 44.44 | Synergistic |
| Koruse | 5.96 | Koruse + K | 73.61 | + 47.22 | Synergistic |
| $K_2SO_4$ | 20.98 | | | | |

The co-toxicity factor (CTF) for the combination of the used fungicides with K (Table 3) indicated that there were synergistic effects for the combination of Koruse, Equation, Champion and Acrobat with K hence it had CTF of 47.22, 44.44, 38.88 and 36.00% respectively. Additive effects were obtained in case of combinations of K with Ridomil and Galbin with CTF of – 2.78 and 2.76%. It is also remarkable that the antagonistic effect was not recorded between the used fungicides and K.

**Field experiment:**

The severity of early blight disease in potato plants under the field conditions during the two successive years (Table 4) ranged between 31.5 to 40% (control values). Spraying the plant with K enhanced the plant control for disease where the disease severity decreased by about 18%. Spraying the potato plants with the used fungicides greatly decreased the disease severity.

**Table (4): Early blight disease severity (%) and the fungicides efficacy on potato plants in two successive seasons ( 2001 , 2002 ) of plant growth.**

| Fungicides | Disease severity % | | | | | | Effecacy % | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Half recommended dose | | | Recommended Dose | | | Half recommended dose | | | recommendedDose | | |
| | 1st | 2ed | mean | 1st | 2ed | Mean | 1st | 2ed | mean | 1st | 2ed | mean |
| Acrobat | 15.00 | 9.66 | 12.33 | 10.00 | 6.25 | 8.13 | 62.50 | 69.33 | 65.98 | 75.00 | 80.15 | 77.58 |
| Acrobat K | 12.00 | 7.50 | 9.75 | 7.00 | 4.66 | 5.83 | 70.00 | 76.13 | 73.07 | 82.50 | 85.20 | 85.85 |
| Galbin | 17.00 | 11.00 | 14.00 | 11.00 | 7.66 | 9.33 | 57.50 | 65.07 | 61.29 | 72.50 | 75.60 | 74.05 |
| Galbin K | 16.00 | 9.25 | 12.63 | 11.66 | 5.25 | 8.96 | 60.00 | 70.63 | 65.98 | 70.85 | 83.33 | 77.09 |
| Champion | 15.66 | 10.50 | 13.08 | 10.33 | 7.00 | 8.67 | 60.85 | 66.66 | 63.76 | 74.17 | 79.10 | 76.64 |
| Champion K | 11.00 | 8.80 | 9.76 | 7.25 | 5.00 | 6.13 | 72.50 | 74.60 | 73.55 | 81.87 | 84.12 | 83.00 |
| Ridomil | 17.00 | 12.33 | 14.67 | 12.00 | 8.25 | 10.13 | 57.50 | 60.85 | 59.78 | 70.00 | 73.80 | 71.90 |
| Ridomil K | 16.66 | 11.66 | 14.16 | 12.50 | 7.00 | 9.75 | 58.35 | 62.98 | 60.67 | 68.75 | 77.77 | 73.26 |
| Equation | 14.66 | 10.66 | 12.66 | 10.50 | 7.33 | 8.92 | 63.35 | 66.15 | 64.75 | 73.75 | 76.73 | 75.29 |
| Equation K | 11.50 | 8.66 | 10.08 | 7.50 | 5.66 | 6.58 | 71.25 | 72.50 | 71.88 | 81.25 | 82.03 | 81.64 |
| Koruse | 20.00 | 13.25 | 16.63 | 13.66 | 9.33 | 12.00 | 50.00 | 57.93 | 53.97 | 65.85 | 71.42 | 68.64 |
| Koruse K | 16.00 | 10.66 | 13.33 | 11.00 | 8.00 | 9.50 | 60.00 | 66.15 | 63.08 | 72.50 | 74.60 | 73.55 |
| $K_2SO_4$ | 25.00 | 20.33 | 22.67 | 18.66 | 17.33 | 18.00 | 37.50 | 39.31 | 38.40 | 53.35 | 48.26 | 50.81 |
| Control | 40.00 | 31.50 | 36.00 | 40.00 | 31.50 | 36.00 | - | - | - | - | - | - |
| LSD at 5% | 3.23 | 3.53 | - | 2.79 | 3.48 | - | - | - | - | - | - | - |

The decrease in disease severity by using half recommended doses of the used fungicides was by slightly lower than their recommended doses. The maximum decrease in disease severity after half doses application was by that of Acrobat, while the minimum was by that of Koruse. After the dose application the maximum decrease in disease severity was for Acrobat, while the minimum was for Koruse. Combination of K with the used fungicides enhanced an additional significant decrease in the disease severity with a highest value by the combination of half recommended dose or dose of Acrobat. It is also important to note that combination of the used fungicides by half recommended doses with K slightly decreased the disease severity than their recommended doses alone especially that of Champion.

The tested fungicides showed an obvious significantly different efficiency in controlling early blight disease (Table 5). The mean efficiency of Acrobat half dose or dose was the highest, while those of Koruse was the lowest. Addition of K increased the efficiency of the used fungicides on the disease with significant values. The combined K increased the efficiency of the half dose of the used fungicides to be near the value for their doses. The highest efficiency was for the combination of K with the recommended dose of Acrobat, while the lowest one was for the combination of K with the half recommended dose of Ridomil.

**Effect of the used fungicides on potato plant growth:**

The growth criteria of potato plants in the form of number of stems/plant, branches number/stem, number of leaves/plant and leaves weight/plant, increased significantly in response to the application of the used fungicides in the two years of study (Table 5). Half recommended dose of these fungicides increased the plant growth criteria by greater rate than their doses. Combining the used fungicides with K mostly decreased the number of stems/plant but it increased leaves number and weight per plant.

**Branching capacity (BC):**

The branching capacity of potato plants (represented as number of branches per plant in Table 5) increased in comparison with the untreated area when the plant was sprayed by the used fungicides. Half recommended dose of all fungicides, except that of Acrobat and Galben increased the BC by greater values than their recommended doses. On the opposite, the doses of each Ridomil and Galben fungicide decreased BC than that of the control. It is also remarkable that combining K with the half doses or doses of the used fungicides led to more enhancement in BC and in most cases it led to counteracting the inhibition that was caused by the increase in fungicides concentration. The highest BC was occurred by the combination of Champion with K which increased BC by 74% as compared with the control. The lowest one was by the application of half dose of Acrobat which inhibited BC by 9%.

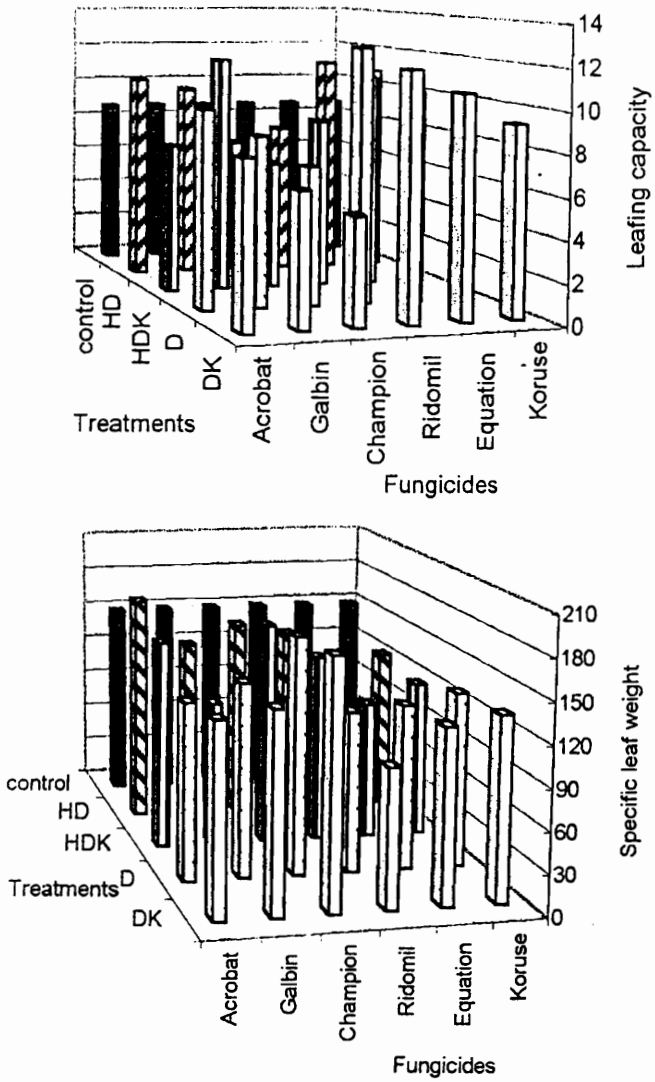
**Table (5): Data of sprayed potato plants by half recommended dose (HD) or dose (RD) of 6 fungicides alone or combined with k**

| Parameter | year | Con-trol | Acrobat | | | | Galbin | | | | Champion | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | HD | HDK | D | DK | HD | HDK | D | DK | HD | HDK | D | DK |
| N umber of stems | 1st | 2.15 | 2.57 | 2.57 | 3.10 | 2.20 | 2.67 | 2.10 | 3.10 | 3.20 | 3.20 | 2.80 | 2.57 | 3.10 |
| | 2ed | 2.45 | 3.77 | 3.70 | 3.43 | 4.03 | 2.63 | 3.63 | 2.97 | 4.23 | 3.53 | 2.73 | 2.80 | 3.37 |
| | mean | 2.30 | 3.17 | 3.14 | 3.27 | 3.12 | 2.65 | 2.87 | 3.04 | 3.72 | 3.37 | 2.77 | 2.69 | 3.24 |
| Branches / plant | 1st | 6.80 | 6.20 | 9.33 | 8.40 | 10.60 | 7.50 | 7.50 | 8.40 | 12.93 | 9.33 | 10.70 | 8.78 | 10.60 |
| | 2ed | 7.55 | 6.23 | 9.26 | 8.23 | 10.36 | 7.35 | 8.33 | 8.68 | 11.67 | 8.90 | 10.73 | 9.20 | 12.11 |
| | mean | 7.18 | 6.22 | 9.30 | 8.32 | 10.48 | 7.43 | 7.92 | 8.54 | 12 30 | 9.12 | 10.72 | 8.99 | 11.36 |
| Number of leaves | 1st | 60 80 | 65.20 | 67.40 | 77.60 | 84.10 | 76.10 | 88.40 | 72.10 | 77.40 | 63.40 | 65.40 | 61.20 | 64.6 |
| | 2ed | 62 50 | 64.80 | 70.90 | 85.10 | 84.40 | 70.80 | 98.00 | 71 40 | 81 20 | 62.70 | 70.80 | 61.40 | 66.10 |
| | mean | 61.65 | 65.00 | 69.15 | 81.35 | 84.25 | 73045 | 93.20 | 71.75 | 79.30 | 63.05 | 68.10 | 61.30 | 65.35 |
| Chlorophyl a | 1st | 9.00 | 12.32 | 10.58 | 11.24 | 11.42 | 8.93 | 8.88 | 10.47 | 11.45 | 9.54 | 11.82 | 10.08 | 11.29 |
| | 2ed | 9.50 | 10.28 | 11.15 | 10.02 | 12.11 | 11.13 | 11.54 | 10.23 | 11.58 | 9.65 | 10.89 | 10.50 | 12.32 |
| | mean | 9.25 | 11.30 | 10.87 | 10.63 | 11.77 | 10.03 | 10.21 | 10.35 | 11.52 | 9.60 | 11.36 | 10.79 | 1.81 |
| Leaves weight | 1st | 3.85 | 3.91 | 4.07 | 4.10 | 4.29 | 4.09 | 4.20 | 4.18 | 4.25 | 4.17 | 4.12 | 4.25 | 4.28 |
| | 2ed | 4.05 | 4.44 | 4.28 | 1.42 | 4.47 | 4.25 | 4.40 | 4.33 | 4.42 | 4.20 | 4.21 | 4.22 | 4.32 |
| | mean | 3.95 | 4.18 | 4.18 | 4.26 | 4.38 | 4.17 | 4.30 | 4.26 | 4.34 | 4.19 | 4.17 | 4.24 | 4.30 |
| Chlorophyll b | 1st | 0.45 | 0.48 | 0.52 | 057 | 0.59 | 0.51 | 0.51 | 0.53 | 0.61 | 0.47 | 0.56 | 0.52 | 0.59 |
| | 2ed | 0.47 | 0.48 | 0.50 | 0.50 | 0.53 | 050 | 0.50 | 0.50 | 0.50 | 0.50 | 0.50 | 0.60 | 0.50 |
| | mean | 0.46 | 0.48 | 0.51 | 0.54 | 0.56 | 0.51 | 0.51 | 0.52 | 0.56 | 0.49 | .53 | 0.56 | 0.55 |
| Leaf N ( %) | 1st | 2.50 | 2.70 | 2.68 | 2.73 | 2.83 | 2.65 | 2.93 | 2.72 | 3.07 | 2.63 | 2.77 | 2.85 | 2.93 |
| | 2ed | 2.80 | 2.72 | 3.10 | 2.88 | 3.28 | 2.85 | 3.30 | 3.12 | 3.22 | 2.87 | 2.98 | 3.41 | 3.37 |
| | mean | 2.65 | 2.71 | 2.89 | 2.81 | 3.06 | 2.75 | 3.12 | 2.92 | 3.15 | 2.75 | 2.88 | 3.00 | 3.15 |
| Leaf P (%) | 1st | 0.50 | 0.66 | 0.69 | .0.60 | 0.62 | 0.58 | 0.63 | 0.61 | 0.64 | 0.49 | 0.60 | 0.51 | 0.66 |
| | 2ed | 0.72 | 0.65 | 2.01 | 0..79 | 0.86 | 0.80 | 0.92 | 0.88 | 1.06 | 0.75 | 0.81 | 0.82 | 0.79 |
| | mean | 0.61 | 0.66 | 1.35 | 0.70 | 0.74 | 0.69 | 0.78 | 0.75 | 0.85 | 0.62 | 0.71 | 0.67 | 0.73 |
| Leaf K(%) | 1st | 3.10 | 3.33 | 3.88 | 3.38 | 3.72 | 3.48 | 3.76 | 3.65 | 4.04 | 3.07 | 3.42 | 2.85 | 3.23 |
| | 2ed | 2.90 | 3.00 | 3.20 | 2.93 | 3.57 | 4.23 | 4.77 | 4.13 | 4.63 | 3.43 | 4.23 | 3.37 | 3.97 |
| | mean | 3.00 | 3.17 | 3.20 | 3.16 | 3.65 | 3.86 | 4.27 | 3.89 | 4.34 | 3.25 | 3.83 | 3.11 | 3.90 |
| Number of tubers | 1st | 8.50 | 10.40 | 11.50 | 10.40 | 11.90 | 11.80 | 13.40 | 9.30 | 11.70 | 12.10 | 13.50 | 12.40 | 13.60 |
| | 2ed | 8.50 | 9.40 | 10.20 | 11.50 | 12.90 | 10.60 | 12.60 | 9.30 | 12.00 | 10.60 | 11.20 | 11.40 | 12.6 |
| | mean | 850 | 9.90 | 10.85 | 10.95 | 12.90 | 11.20 | 13.00 | 9.30 | 11.85 | 11.35 | 12.35 | 11.90 | 13.10 |
| Tubers weight | 1st | 510 | 636 | 1089 | 1028 | 736 | 736 | 828 | 525 | 800 | 761 | 860 | 800 | 648 |
| | 2ed | 597 | 852 | 1112 | 1022 | 644 | 778 | 665 | 665 | 587 | 825 | 842 | 725 | 775 |
| | mean | 554 | 744 | 1110 | 1025 | 690 | 757 | 746 | 595 | 694 | 793 | 851 | 763 | 712 |
| Tuber dry weight | 1st | 16.60 | 15.51 | 15079 | 15.98 | 16.94 | 18.96 | 19.28 | 16.76 | 17.41 | 15.77 | 16.95 | 16.55 | 16.66 |
| | 2ed | 15.50 | 16.57 | 18063 | 17.67 | 18.67 | 17.00 | 17.67 | 18.67 | 19.33 | 17.00 | 17.33 | 17.67 | 17.33 |
| | mean | 16.05 | 16.04 | 17.21 | 16.83 | 17.81 | 17.98 | 18.48 | 17.72 | 18.37 | 16.39 | 17.14 | 17.11 | 17.00 |
| Specific rafity(%) | 1st | 1.06 | 1.09 | 1.10 | 1.08 | 1.07 | 1.07 | 1.07 | 1.08 | 1.09 | 1.06 | 1.08 | 1.06 | 1.07 |
| | 2ed | 1.07 | 1.09 | 1.10 | 1.08 | 1.07 | 1.08 | 1.07 | 1.08 | 1.08 | 1.06 | 1.08 | 1.07 | 1.08 |
| | mean | 1.07 | 1.09 | 1.10 | 1.08 | 1.07 | 1.07 | 1.07 | 1.08 | 1.09 | 1.06 | 1.08 | 1.07 | 1.08 |
| Starch% | 1st | 7.10 | 16.60 | 17.54 | 13.60 | 13.14 | 12.00 | 12.53 | 15.05 | 16.97 | 7.43 | 7.12 | 10.60 | 13.13 |
| | 2ed | 8.50 | 16.32 | 17.48 | 13.59 | 15.55 | 13.25 | 12.84 | 13.96 | 14.77 | 10.99 | 13.33 | 12.86 | 13.95 |
| | mean | 7.80 | 16.46 | 17.51 | 13.60 | 14.35 | 12.63 | 12.69 | 14.51 | 15.87 | 9.21 | 10.23 | 11.73 | 13.54 |
| Tuber N (%) | 1st | 1.65 | 1.65 | 1.67 | 1.70 | 1.72 | 1.78 | 1.83 | 1.86 | 1.90 | 1.63 | 1.70 | 1.8 | 1.83 |
| | 2ed | 1.55 | 1.60 | 1.68 | 1.57 | 1.82 | 1.73 | 1.73 | 1.83 | 1.78 | 1.65 | 1.73 | 1.72 | 1.78 |
| | mean | 1.60 | 1.63 | 1.68 | 1.64 | 1.77 | 1.76 | 1.78 | 1.85 | 1.84 | 1.64 | 1.72 | 1.76 | 1.81 |
| TuberP (%) | 1st | 0.29 | 0.27 | 0.28 | 0.29 | 0.29 | 0.28 | 0.31 | 0.27 | 0.31 | 0.26 | 0.30 | 0.31 | 0.32 |
| | 2ed | 0.30 | 0.30 | 0.31 | 0.32 | .34 | 0.39 | 0.34 | .35 | 0.38 | 0.32 | 0.33 | 0.38 | 0.39 |
| | mean | 0.30 | 0.29 | 0.30 | 0.31 | 0.32 | 0.34 | 0.33 | .31 | 0.35 | 0.29 | 0.32 | 0.35 | 0.36 |
| Tuber K (%) | 1st | 1.65 | 1.65 | 1.65 | 1.67 | 1.75 | 1.90 | 1.83 | 1.95 | 2.02 | 1.73 | 1.80 | 1.83 | 1.83 |
| | 2ed | 1.80 | 1.80 | 1.83 | 1.88 | 1.95 | 1.78 | 1.81 | 1.88 | 2.00 | 1.78 | 1.82 | 1.88 | 1.92 |
| | mean | 1.73 | 1.73 | 1.74 | 1.78 | 1.85 | 1.84 | 1.82 | 1.92 | 2.01 | 1.76 | 1.81 | 1.86 | 1.88 |
| Tuber $NO_3$ (ppm) | 1st | 196 | 139 | 151 | 141 | 159 | 182 | 185 | 186 | 195 | 135 | 137 | 126 | 165 |
| | 2ed | 203 | 183 | 189 | 180 | 205 | 194 | 197 | 202 | 205 | 182 | 190 | 198 | 196 |
| | mean | 200 | 161 | 170 | 161 | 182 | 188 | 191 | 194 | 200 | 185 | 164 | 162 | 180 |

**Leafing capacity (LC):**

Most treatments of the used fungicides increased LC of potato plants (Fig. 1). The half recommendeddoses had greater effect than the recommended doses of the fungicides except Ridomil. Combining K with the fungicides reduced the LC in comparison with the control. The highest LC was occurred by dose of Ridomil which increased LC by 47%. The lowest LC appeared after the application of the dose of Ridomil combined with K which decreased the LC by 39%.

Fig. (1): Leafing capacity ( leaf/branch) and specific leaf weight (g/leaf) in potato plant under the effect of some fungicides alone or combined with potassium.



**Table(5)continue**

| Paramater | Year | Contro | Ridomil | | | | Equation | | | | Knruse | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | HD | HDK | D | DK | HD | HDK | D | DK | HD | HDK | D | DK |
| Number stems | 1 st | 2.15 | 2.33 | 2.33 | 2.90 | 2.10 | 2.33 | 2.10 | 2.43 | 2 20 | 3.20 | 2 10 | 2.33 | 2.70 |
| | 2 ed | 2.45 | 2.63 | 3.53 | 2.73 | 3.23 | 2 63 | 3.30 | 2.73 | 3 80 | 2 63 | 3.50 | 2.73 | 3.60 |
| Branches / plant | mean | 2.30 | 2.48 | 2.93 | 2.82 | 2.67 | 2.48 | 2.70 | 2 58 | 3 00 | 2.92 | 2.80 | 2.53 | 3.15 |
| | 1 st | 6.80 | 9.25 | 9.48 | 5.76 | 8.65 | 8.13 | 9.60 | 3.85 | 7 27 | 7.35 | 9.48 | 7.63 | 8.78 |
| | 2 ed | 7.55 | 10.42 | 9.78 | 8.51 | 9.21 | 8.58 | 9.94 | 7 48 | 9 42 | 7 93 | 9.79 | 7.51 | 9.60 |
| Number of leaves | mean | 7.18 | 9 43 | 9 63 | 0.14 | 8.93 | 8 38 | 9 77 | 7 17 | 8 35 | 7.64 | 9.64 | 7.57 | 9.19 |
| | 1 st | 60.8 | 74.2 | 76.2 | 84.30 | 103.7 | 91.6 | 102.2 | 76 0 | 85 0 | 80 2 | 93.6 | 74.7 | 84.0 |
| | 2 ed | 62.5 | 75.5 | 88 2 | 91.1 | 106.2 | 95.2 | 108.5 | 84 8 | 92 2 | 84 1 | 97.9 | 80.1 | 85.7 |
| Leaves weight | mean | 61.7 | 74.9 | 82.2 | 87.7 | 10.29 | 93.4 | 105.4 | 80.4 | 88 6 | 82 2 | 95.9 | 77.4 | 84.9 |
| | 1 st | 9.00 | 10.29 | 11.91 | 10.67 | 11.34 | 9 01 | 11.07 | 9.62 | 11 46 | 10 10 | 12.15 | 10.14 | 11.00 |
| | 2 ed | 9.50 | 10.96 | 11.30 | 10.23 | 10.82 | 9.39 | 10.73 | 10.00 | 11 19 | 10.20 | 13.32 | 9.90 | 00.79 |
| Chlorophyll a | mean | 9.25 | 10.63 | 11.61 | 10.45 | 4.39 | 9.20 | 10.90 | 9.81 | 11 33 | 10 15 | 11.24 | 10.02 | 11.40 |
| | 1 st | 3.85 | 4.31 | 4.39 | 4.18 | 4.50 | 4.05 | 4.28 | 4.14 | 4 28 | 4.10 | 4.33 | 4.15 | 4.22 |
| | 2 ed | 4.05 | 4.42 | 4.43 | 4.28 | 4.50 | 4.17 | 4.23 | 4.35 | 4 42 | 4 22 | 4.32 | 4.32 | 4.35 |
| Chlorophyll b | mean | 3.95 | 4.37 | 4.41 | 4.23 | 4.45 | 4.11 | 4.26 | 4.25 | 4 35 | 4.16 | 4.33 | 4.24 | 4.29 |
| | 1 st | 0.45 | 0.53 | 0.54 | 0.53 | 0.59 | 0.52 | 0.56 | 0.35 | 0.55 | 0.52 | 0.55 | 0.50 | 0.56 |
| | 2 ed | 0.47 | 0.47 | 0.50 | 0.50 | 0.50 | 0.50 | 1.50 | 0.50 | 0 60 | 0 47 | 0.50 | 0.50 | 0.50 |
| Leaf N (%) | mean | 0.46 | 0.50 | 0.52 | 0.52 | 0.55 | 0.51 | 0.53 | 0.52 | 0.58 | 0.50 | 0.53 | 0.50 | 0.53 |
| | 1 st | 2.50 | 2.68 | 2.88 | 2.93 | 3.05 | 2.64 | 2.83 | 2.98 | 2 82 | 2.83 | 2.97 | 2.93 | 2.93 |
| | 2 ed | 2.80 | 2.97 | 2.92 | 3.10 | 3.23 | 2.82 | 3.13 | 2.93 | 3.07 | 2.98 | 3.12 | 3.03 | 3.08 |
| Leaf P (%) | mean | 2.65 | 2.83 | 2.90 | 3.02 | 3.14 | 2.73 | 2.98 | 2.96 | 2.95 | 2.91 | 3.05 | 2.98 | 3.01 |
| | 1 st | 0.50 | 0.60 | 0.67 | 0.62 | 0.63 | 0.61 | 0.65 | 0.59 | 0.70 | 0.59 | 0.69 | 0.51 | 0.61 |
| | 2 ed | 0.72 | 0.83 | 0.94 | 0.84 | 0.72 | 0.83 | 0.93 | 0.80 | 0 92 | 0.91 | 1.04 | 0.89 | 1.01 |
| Leaf K ( %) | mean | 0.61 | 072 | 0.81 | 0.37 | 0.68 | 0.72 | 0.79 | 0.70 | 0 81 | 0.75 | 0.87 | 0.70 | 0.81 |
| | 1 st | 3.10 | 3.15 | 3.76 | 3.65 | 4.10 | 3.24 | 3.68 | 3.43 | 3 07 | 3.16 | 3.16 | 3.25 | 3.59 |
| | 2 ed | 2.90 | 4.13 | 4.53 | 4.47 | 4.47 | 4.10 | 4.33 | 4.00 | 4.33 | 3.93 | 4.43 | 4.13 | 4.60 |
| Number of tubers | mean | 3.00 | 3.64 | 4.15 | 4.06 | 4.29 | 3.67 | 4.01 | 3.72 | 3 70 | 3.55 | 3.80 | 3.69 | 4.10 |
| | 1 st | 8.50 | 9.30 | 12.00 | 11.30 | 10.40 | 10.00 | 11.60 | 9.20 | 11.30 | 13.10 | 14.70 | 11.90 | 13.50 |
| | 2 ed | 8.50 | 10.40 | 11.30 | 10.50 | 11.40 | 11.50 | 13.20 | 10.80 | 13.00 | 11.50 | 12.70 | 10.10 | 12.80 |
| Tubers weight | mean | 8.50 | 9.85 | 11.65 | 10.90 | 10.90 | 10.75 | 12.40 | 10.00 | 12 15 | 12.30 | 13.70 | 11.00 | 13.15 |
| | 1 st | 510 | 880 | 803 | 778 | 857 | 558 | 1036 | 969 | 847 | 756 | 729 | 661 | 636 |
| | 2 ed | 597 | 786 | 820 | 742 | 842 | 618 | 645 | 706 | 751 | 609 | 692 | 661 | 573 |
| Tuber dry weight | mean | 554 | 833 | 812 | 760 | 849 | 588 | 840 | 838 | 799 | 682 | 710 | 661 | 605 |
| | 1 st | 16.60 | 16.30 | 16.13 | 17.49 | 18.25 | 16.46 | 18.82 | 16.75 | 18 91 | 16.27 | 16.89 | 17.22 | 18.08 |
| | 2 ed | 15.50 | 17.33 | 16.00 | 18.33 | 18.67 | 18.00 | 17.67 | 18.33 | 18.67 | 18.00 | 17.00 | 18.67 | 18.33 |
| Specific grafity | mean | 16.05 | 16.82 | 16.07 | 17.91 | 18.46 | 17.23 | 18.25 | 17.58 | 18.79 | 17.14 | 16.95 | 17.95 | 18.21 |
| (%) | 1 st | 1.06 | 1.09 | 1.10 | 1.08 | 1.06 | 1.09 | 1.09 | 1.09 | 1 07 | 1.09 | 1.08 | 1.07 | 1.08 |
| | 2 ed | 1.07 | 1.10 | 1.09 | 1.08 | 1.08 | 1.09 | 1.09 | 1.09 | 1.08 | 1.09 | 1.08 | 1.08 | 1.08 |
| | mean | 1.07 | 1.09 | 1.09 | 1.08 | 1.07 | 1.09 | 1.09 | 1.09 | 1 07 | 1.09 | 1.08 | 1.08 | 1.08 |
| Starch % | 1 st | 7.10 | 16.56 | 17.30 | 14.67 | 11.20 | 16.41 | 14.62 | 16.24 | 12.74 | 16.67 | 13.81 | 11.68 | 14.43 |
| | 2 ed | 8.50 | 17.19 | 16.53 | 14.85 | 13.83 | 16.60 | 16.69 | 16.61 | 13.33 | 16.74 | 15.14 | 15.11 | 15.15 |
| | mean | 7.80 | 16.88 | 16.92 | 14.76 | 12.52 | 16.51 | 15.66 | 16.43 | 13.04 | 16.71 | 14.48 | 13.40 | 14.79 |
| Tuber N (%) | 1 st | 1.65 | 1.85 | 1.88 | 1.98 | 2.12 | 1.70 | 1.78 | 1.77 | 1 87 | 1.73 | 1.78 | 1.77 | 1.83 |
| | 2 ed | 1.55 | 1.80 | 1.82 | 1.92 | 1.93 | 1.67 | 1.73 | 1.73 | 1 73 | 1.72 | 1.73 | 1.77 | 180 |
| | mean | 1.60 | 1.83 | 1.85 | 1.95 | 2.03 | 1.69 | 1.76 | 1.75 | 1.80 | 1 73 | 1.76 | 1.77 | 1.82 |
| Tuber P(%) | 1 st | 0.29 | 0.32 | 0.33 | 0.34 | 0.35 | 0.82 | 0.30 | 0.34 | 0.35 | 0.27 | 0.29 | 0.32 | 0.33 |
| | 2 ed | 0.30 | 0.36 | 0.41 | 0.47 | 0.52 | 0.32 | 0.32 | 0.36 | 0.40 | 0.34 | 0.35 | 0.37 | 0.38 |
| | mean | 0.30 | 0.34 | 0.37 | 0.41 | 0.44 | 0.30 | 0.31 | 1.35 | 0 38 | 0.31 | 0.32 | 0.35 | 0.36 |
| Tuber k(%) | 1 st | 1.65 | 1.77 | 1.83 | 1.88 | 2.00 | 1.72 | 0.82 | 1.80 | 1 88 | 1.78 | 1 82 | 1.80 | 1.92 |
| | 2 ed | 1.80 | 2.00 | 2.10 | 2.07 | 2.28 | 1.83 | 1.93 | 1.98 | 2 07 | 2.07 | 1.98 | 1.93 | 2.10 |
| | mean | 1.73 | 1.89 | 1.97 | 1.98 | 2.14 | 1.78 | 1.88 | 1.89 | 1 98 | 1 93 | 1.90 | 1.87 | 2.01 |
| Tuber $NO_3$ (ppm) | 1 st | 196 | 185 | 180 | 190 | 201 | 154 | 165 | 174 | 185 | 153 | 146 | 155 | 165 |
| | 2 ed | 203 | 195 | 205 | 197 | 208 | 185 | 187 | 193 | 199 | 177 | 183 | 187 | 191 |
| | mean | 200 | 190 | 193 | 194 | 204 | 170 | 176 | 184 | 192 | 165 | 165 | 171 | 178 |

**Specific leaf weight (SLW):**

The used half recommended dose and the recommended dose of the fungicides reduced the SLW of potato plants except those of Champion and the half dose of Acrobat alone or combined with K (Fig. 1). The lowest SLW was after spraying the half dose of Equation which reduced the SLW by 34% if compared with the control. The increase of fungicides concentration from half dose to the dose mostly led to more reduction in the SLW. Also, the combination of K with the fungicides magnified their reduction to SLW especially their doses. On the opposite, the dose of Champion led to higher SLW than its half dose. Also, addition of K in combination with Champion increased SLW of potato plants but with lower rate without the recommended dose than for half dose treatments. For the half dose of Acrobat, K combination decreased the increase in SLW from 16% to 4%.

**Table 5 continue, the statistical analysis ANOVA factorial analysis for the obtained data of potato plant. * significant at P<0.05, ** significant at P<0.01 and NS non significant.**

| Fungicide | Year | Fungicide (A) | Dose (B) | K ( C ) | Interactions | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | AxB | AxC | BxC | AxBxC |
| Stem no. | 1st | * | NS | * | ** | ** | ** | ** |
| | 2ed | * | NS | * | NS | NS | NS | NS |
| Branches/plant | 1st | * | NS | * | ** | ** | ** | ** |
| | 2ed | NS | NS | * | NS | NS | NS | NS |
| Leaves no. | 1st | * | NS | * | ** | ** | ** | NS |
| | 2ed | * | NS | * | * | * | Ns | * |
| Leaves weight | 1st | ** | NS | * | ** | ** | ** | ** |
| | 2ed | NS | NS | NS | NS | NS | NS | NS |
| Chlorophyll a | 1st | * | * | * | * | * | NS | NS |
| | 2ed | * | * | * | NS | NS | NS | NS |
| Chlorophyll b | 1st | NS | * | * | * | * | * | * |
| | 2ed | NS | * | * | NS | NS | NS | NS |
| Leaf N | 1st | * | * | * | NS | * | NS | * |
| | 2ed | NS | NS | * | NS | NS | NS | NS |
| Leaf P | 1st | * | NS | * | * | * | NS | NS |
| | 2ed | * | NS | * | NS | NS | NS | NS |
| Leaf K | 1st | * | NS | * | NS | NS | * | * |
| | 2ed | NS | NS | * | NS | NS | NS | NS |
| Tubers no. | 1st | * | NS | * | * | NS | NS | * |
| | 2ed | * | NS | * | * | NS | * | ND |
| Tubers weight | 1st | * | NS | * | * | * | NS | NS |
| | 2ed | * | NS | NS | * | * | NS | NS |
| Tuber dry weight | 1st | * | NS | * | * | * | NS | NS |
| | 2ed | * | * | NS | NS | NS | NS | NS |
| Specific gravity | 1st | * | NS | NS | NS | NS | NS | NS |
| | 2ed | NS | NS | NS | NS | NS | NS | NS |
| Starch | 1st | * | * | NS | * | * | NS | NS |
| | 2ed | * | * | NS | * | * | NS | NS |
| Tuber N | 1st | NS | * | * | * | NS | NS | NS |
| | 2ed | NS | * | * | NS | NS | NS | NS |
| Tuber P | 1st | * | * | * | * | NS | NS | * |
| | 2ed | * | * | NS | NS | NS | NS | NS |
| Tuber K | 1st | * | * | * | * | * | * | * |
| | 2ed | NS | * | * | NS | NS | NS | NS |
| Tuber NO3 | 1st | * | * | * | * | * | * | * |
| | 2ed | * | * | * | NS | NS | NS | NS |

**Photosynthetic pigments:**

The applied fungicides increased significantly the photosynthetic pigments (Chlorophyll a and b) in potato leaves (Fig. 2). The recommended fungicides dose greatly increased chlorophyll a and b as compared with their half dose. The highest values for each chlorophyll a and b under the effect of half dose were 4.37 and 0.53 mg/g f.wt under the effect of Ridomil, while under the dose application they were 4.26 and 0.56 mg/g f.wt under dose of Acrobat and Champion. Addition of K led to more enhance for the metabolism of chlorophyll a and b over what caused by using the fungicides

alone. The greatest enhancement was by the combination of K with Ridomil dose. It is also remarkable that combination of K with the half dose of each Champion, Ridomil, Equation and Koruse increased the contents of chlorophyll a and b to exceed their contents under the application of these fungicides dose.

The unequal effect of the used fungicides on chlorophyll a and b metabolism disturbed their ratio in potato plant leaves. Chlorophyll a/b ratio decreased in the sprayed plants by the half recommended dose or dose of the used fungicides, except the half recommended dose of each Acrobat and Equation, in comparison with unsprayed control. Dose of most fungicides led to more decrease in chlorophyll a/b ratio as compared with their half doses. Also, K application in combination led to more decrease in a/b ratio. The content of the two pigments indicates that the decrease in their ratio was a result of the increase by greater rate in chlorophyll b than in chlorophyll a in sprayed plants by the used fungicides as single or combined with K.

**Leaf chemical constituent:**

The contents of each N, P and K in potato plant leaves (Fig. 3) varied significantly in response to the applied fungicides and K treatments. All of the used fungicides increased the contents of leaf N, P, and K with a greater rate with their doses than with their half recommended doses. Combining K with the half dose or recommended dose of the used fungicides increased the contents of the three nutrient elements than if they were applied alone. The total of the three elements increased, higher values were mostly by the half doses of the used fungicides combined with K. The highest value of NPK was obtained by the combination of Galben dose with K, while the lowest one was by the half dose of Champion. It is also notable that the increase in K content in the leaves by the used fungicides was greater than in both P and N contents.

**Potato Yield:**

The used fungicides increased significantly the number of tubers (NT) in potato plant (Table 4). The maximum value of NT, which was greater by 19% of the control, was produced in sprayed plants by the combination of K with the half recommended dose of Koruse. The increase in NT was by higher value by the dose application of Acrobat, Champion and Ridomil, but it was by lower value by the dose of Galbin, Equation and Koruse than what was occurred by their half doses. Spraying potato plants by the half dose of the used fungicides combined with K, except that of Acrobat increased NT by greater value than the fungicides alone.

The sprayed fungicides increased total tubers weight per plant (TTW) as shown in Table (4). Except for the dose of each Acrobat and Equation, the dose of the other fungicides increased TTW by lower value than their half dose. Addition of K increased the TTW of the sprayed plants by the half dose of all fungicides, except Galbin and Ridomil, but it lowered the TTW in sprayed plants with the fungicides dose.

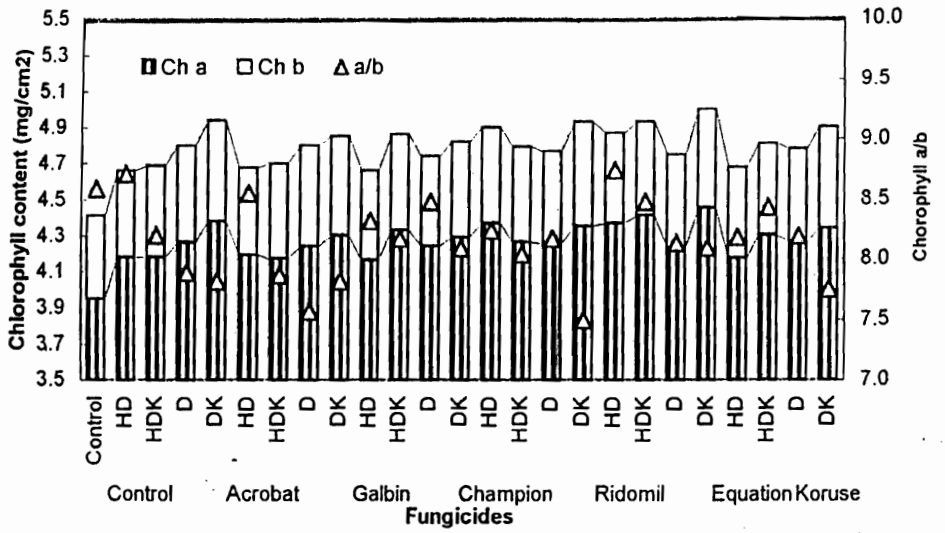



**Fig. (2): The contents of chlorophyll a and b and their ratio in potato leaves under effect of some fungicides dose (D) or half dose (HD) alone or combined with potassiuim.**

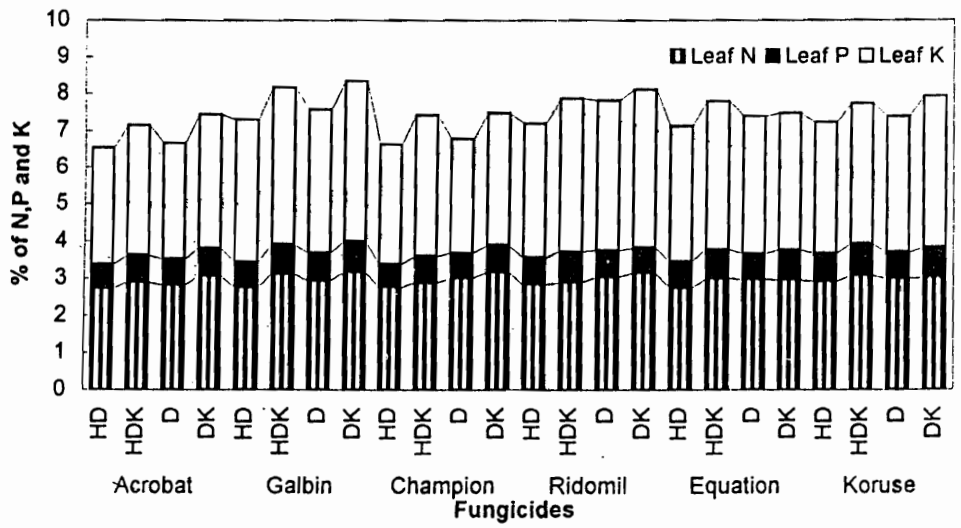



**Fig. (3): The % of control contents of nitrogen, phosphorus and potassium in potato leaves un effect of some fungicides dose (D) or half dose (HD) alone or combined with potassiuin**

The highest value of TTW was recorded in sprayed potato plants by the half dose of Acrobat combined with K. In general, combining K with the half doses of the used fungicides increased the TTW than their doses as a single or combined with K.

The tuber weight (TW) differed remarkably in response to spraying by the used fungicides as single or combined with K (Table 4). The dose or half dose of the used fungicides, except Ridomil and Acrobat decreased TW. In general, combining K with their half dose or dose led to more decrease in TW as compared with the fungicides alone, while K combination with their dose decreased TW lower than the control. The lowest value of TW was under the dose of Koruse combined with K. On the opposite, all treatments of Ridomil and most treatments of Acrobat increased TW than the control. The highest value of TW occurred after the application of the half dose of Acrobat combined with K. The specific gravity (SG) of the tubers was not changed greatly by the used fungicides (Table 5). Most fungicides especially when combined with K spraying slightly increased the tubers SG. The highest SG (greater by 2.8% than the control) was recorded after the application of half dose of Acrobat combined with K.

**Specific yield (SY):**

The used fungicides treatment, except the half recommended dose of Acrobat and dose of Galbin increased specific yield of potato plants significantly (Fig. 5). Increase the concentration from half dose to the recommended dose for all fungicides, except Acrobat and Equation increased the SY of potato plants. This is due mainly to a great increase in potato plants vegetative growth and a slightly to the decrease in tubers weight. Combination of K with the half dose of Acrobat, Galbin and Champion increased the SY over what was caused by their dose, while the combinations for the other fungicides led to slightly lower SY. The highest value of specific yield (171% of control) was obtained by the application of the half dose of Acrobat combined with K. This indicates that K could be used to decrease the fungicides concentration and obtain a similar effect on the disease control.

**Tuber quality:**

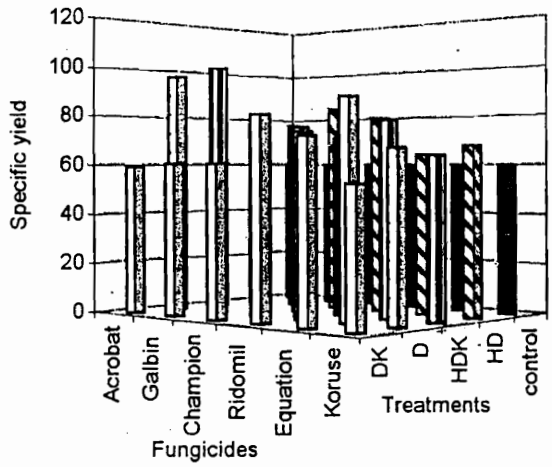
**a- Starch content:**

Starch contents (Table 4) were mostly doubled in the produced potato tubers by the application of fungicides alone or combined with K. Increasing the concentration from half recommended dose to the recommended dose of Acrobat, Ridomil, and Equation led to lower starch content whether they applied as a single or combined with K. Opposite trend was exhibited by Galbin, and Champion. The increase in tuber starch by the combination of the half dose of most fungicides with K was greater than by their doses as a single. The highest starch content was recorded after spraying the half dose of Acrobat combined with K.

**b- Chemical constituents of tubers:**

The content of N, P and K in potato tuber was increased after spraying the applied treatments of the used fungicides singly or combined with K (Fig. 5).

Fig. (4): Specific yield of potato plant under the effect of some fungicidesdose (D) or half dose (HD) alone or combined with potassium.



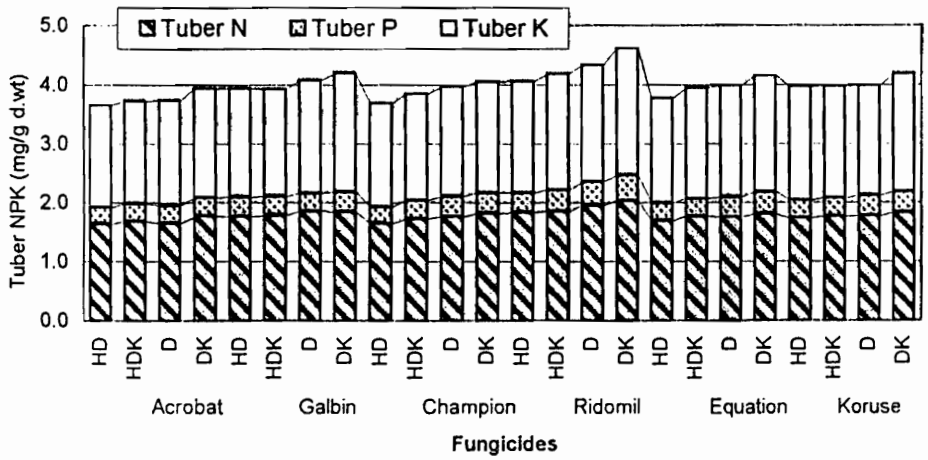




**Fig. (5): The % of control contents of NPK in potato tuber under the effect of half dose (HD) or dose (D) of some fungicides alone or combined with K.**

The dose of the used fungicides increased contents of N, P and K than their recommended doses, the maximum was with that recommended dose of Ridomil. Also, K increased the three elements total with greater values when it was combined with the dose than with the half dose of the used fungicides. The maximum total of the three elements was under the dose of Ridomil combined with K.

**c- Tuber nitrate content ($NO_3^-$%):**

Nitrate content in potato tubers (Table 4) decreased when the plants were sprayed by the used fungicides. Combining these fungicides with K caused an increase in tuber nitrate content as compared with them alone. The increase in nitrate content exceeded slightly the control value under the effect of the recommended dose of each Galbin and Ridomil combined with K.

**Overall effect of the used fungicides:**

The differences from the control (positive or negative), which were occurred by the used fungicides singly or combined with K on the vegetative or yield of potato plant, were calculated as percentage of the control, summed together to represent an overall effect (OE) with a maximum value of 1800% represented in Figure (6a). The OE data indicate that all of the used fungicides in the present study had resulted in positive effects ranged between a maximum of 553 with the recommended dose of Galbin and a minimum of 182 with the half dose of Champion. The half dose of the used fungicides, except Koruse led to lower OE than their dose. The half dose or dose of Ridomil led to the higher OE in compared with the similar treatments of the other fungicides. Combination of K with the half dose or dose of the used fungicides increased their OE greatly. Combination of K with the half recommended doses of all fungicides increased their OE to exceed that of recommended dose as a single OE .The OE of the combination of Acrobat and Equation exceed also the OE of that of recommended doses combined with K. The highest value of OE under the half dose combined with K was for Acrobat that was also higher than the OE of all treatments of the used fungicides except the combination of Galbin dose with K.

The enhancement of the used fungicides by half recommended dose or dose was mostly lower for the vegetative growth than for the tuber yield. Combining K with the half doses or dose of the used fungicides, except the half doses of Acrobat and Ridomil and doses of Ridomil and Equation enhanced the vegetative growth of the potato plants by greater rate than the tuber yield. This showed that vegetative growth enhancement was mainly due to the K spray. It is also notable that the increase in OE by Galbin dose was a result of the great increase in the potato vegetative growth.

**Actual fungicide effectiveness (AFE):**

The actual fungicide effectiveness calculated on the tubers yield base (Fig. 6b) indicated that all of the used fungicides exhibited great effectiveness on the early blight disease which ensured vigorous vegetative growth and good tubers yield. Dose of each fungicide in comparison with the half recommended dose acquire higher effectiveness.

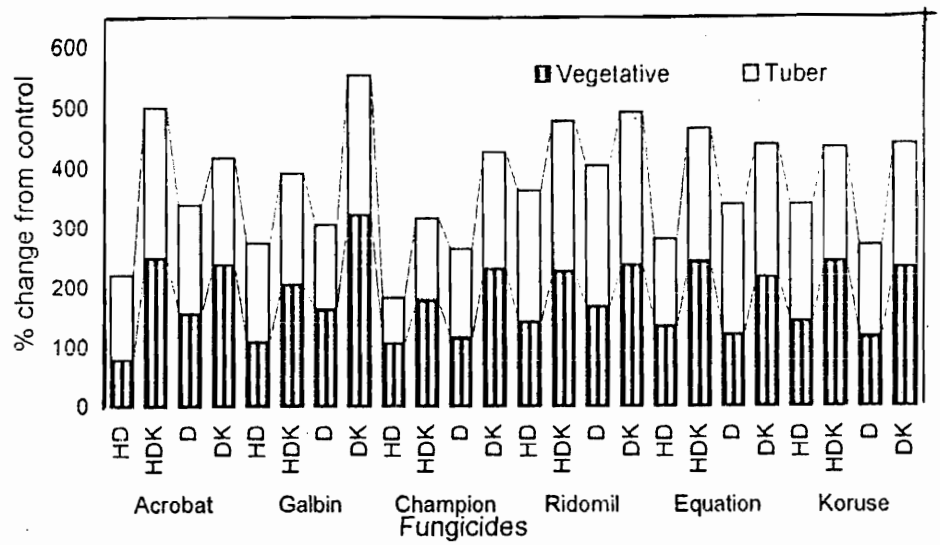



**Fig. (6a): The total, vegetative and tuber differences as % from the control for the studied characters in potato plant under the effect of some fungicides dose (D) or half dose (HD) alone or combined with K.**

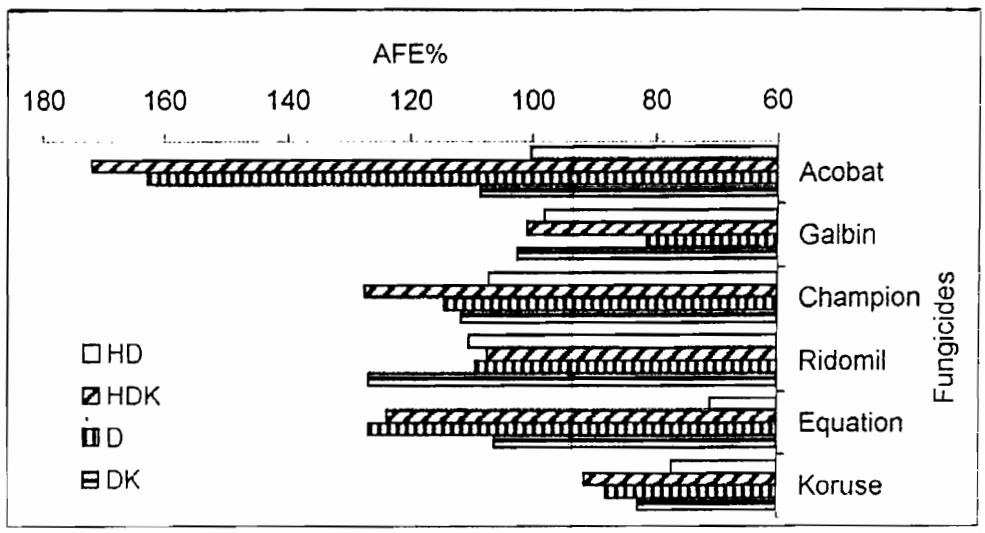



Fig. (6b): Actual fungicide effective ness (AFE%) for half dose (HD) or dose (D) of some fungicides alone or combined with K on the control of early blight disease in potato.

Combining K with each fungicide half dose increased its AFE so that it became higher than the AFE of its dose, except for Ridomil and Equation where the AFE of their half recommended doses combined with K was slightly lower. Acrobat dose and half dose combined with K had the highest AFE, with a higher value for the later treatment. On the opposite, combining K with the dose of all fungicides, except Galin and Ridomil lowered their AFE especially for Acrobat.

## DISCUSSION

The growth of *Alternaria solani* in laboratory was affected greatly by the addition of the used fungicides in its growth medium. Champion was the most potent compounds where it inhibited the fungal growth in a very low concentration, while Koruse acquired the least toxic effect and the widest confidence limit for application as also found by Zein, *et al.* (2002). Addition of K by the used concentration in this study to the fungus medium inhibited the fungal growth with a $IC_{50}$ of 20.98ppm. This recorded inhibition value for K may be due to its disturbance for the medium nutrient balance. The co-toxicity factor for the combination of Koruse, Equation, Champion and Acrobat with K indicated a synergistic effect for K for those fungicides. Additive effects were by Ridomil and Galbin with co-toxicity factors of –2.78 and 2.76%. These results agreed with those studies of Zein *et al.* (1990&2002).

The severity of early blight on potato plants in the field during the two successive years of the study ranged between 31 to 40%. Spraying the plant with K improved plant control for the disease that led to a decrease in the disease severity by about 18%. Spraying the potato plants with the used fungicides decreased the disease severity with a lower value for their half recommended doses than recommended doses. The lowest disease severity was after the application of Acrobat dose. Combination of the used fungicides with K enhanced an additional decrease in the disease severity with a highest value by the combination of half dose or dose of Acrobat. This revealed an obvious and significant efficiency for the used fungicides in controlling early blight disease with a highest for Acrobat and a lowest for Koruse half dose and dose. The combined K increased the efficiency of the half dose of the used fungicides to be near to their doses also with a highest for Acrobat. Shtienberg *et al.* (1996), Mohit *et al.* (1997) and Sowant *et al.* (1999) found similar results.

The growth criteria of potato plants were improved remarkably after the application of the used fungicides at their half recommended doses acquired greater effect than doses. This was clear in the increase in branching and leafing capacities. Combining the fungicides with K enhanced the plant growth as it increased leaves number and weight per plant in addition to branching and leafing capacities as indicated also by Abdel-Ati (1998) and Ashour and Sarhan (1998). The branching capacity reached to 74% by the combination of Champion with K. Most treatments of the used fungicides reduced the specific leaf weight (SLW) of potato plants. The

increase in their concentrations from half recommended doses to the doses mostly led to more reduction in the SLW and their combinations with K magnified their reduction to SLW especially their doses. On the opposite, Champion increased SLW especially its dose and with K it increased SLW of potato plants but with lower rate for dose than for half dose treatments. Also, K combination with Acrobat half dose decreased its increase to SLW from 16% to 4%.

The photosynthetic pigments (Chlorophyll a and b) increased greatly with the used fungicides doses as compared with their half dose. The highest values of chlorophyll a and b were by dose of Acrobat and Champion respectively. The applied K led to more enhancing for the metabolism of chlorophyll a and b with a greatest enhancement by the combination of K with Ridomil dose. It is also remarkable that combination of K with the half dose of each Champion, Ridomil, Equation and Koruse increased the contents of chlorophyll a and b over their contents under the application of these fungicides dose. This could be due to the decrease in disease severity or to the enhancement for K to the process of these photosynthetic pigments metabolism. This unequal effect of the used fungicides on chlorophyll a and b metabolism disturbed their ratio in potato plant leaves where a/b ratio decreased by lower value by the half dose than the dose of them, except the half dose of each Acrobat and Equation. K application, in combination, lead to more decrease in a/b ratio. The content of the two pigments indicates that the decrease in their ratio was a result of the increase, by greater rate, in chlorophyll b than in chlorophyll a in sprayed plants by the used fungicides as a single or combined with K.

The leaf content of each N, P and K increased in response to the applied fungicides alone or combined with K and with greater rate with their doses than half doses. Ashour and Sarhan (1998) found K enhancement for potato plants NPK. The combination of K with the half dose of the used fungicides increased contents of the three nutrient elements than with their doses alone. This was clear of the three elements total which increased by higher values by the half doses of the used fungicides combined with K than by their doses. The increase in leaves K content by the used fungicides was greater than in the contents of both P and N. The highest value of NPK was obtained by the combination of Galben dose with K, while the lowest was by the half dose of Champion.

The potato yield increased significantly by the used fungicides as indicated by the increases in number of tubers (NT) and total tubers weight (TTW). Spraying potato plants by K combined with the half dose of the used fungicides increased NT and TTW by greater values than by their doses as a single or combined with K. On the opposite, the tuber weight (TW) was decreased in response to spraying by the half recommended dose or dose of the used fungicides as a single or combined with K, except all treatments of Ridomil and most treatments of Acrobat who increased TW. The highest TW was produced by plants sprayed by the half dose of Acrobat combined with K. The data of each NT and TW showed that half doses of the fungicides as compared with their doses were better for obtaining high tubers productivity. Except for Acrobat and Ridomil, the used fungicides led to the production of

great number of smaller size tubers as compared with the control. The best production in NT and TW was by the application of Acrobat half dose combined with K that led to the production of greater number of greater weight tubers.

The specific yield was accelerated by most of the used fungicides treatments. The increase in fungicide concentration from half dose to the dose (except for Acrobat and Equation) or combining them with K improved the specific yield of potato plants. This due mainly to both a great increase in potato plants vegetative growth not a decrease in tubers weight. Potassium increased tuber production by about 20% (Tawfik, 2001). Combination of K with the half dose of Acrobat, Galbin and Champion increased potato specific yield over that was caused by their dose. The highest (171% of control) was obtained by Acrobat. This indicates that K application combined with the half dose could be used to obtain similar or better results for the fungicides effect on potato plants.

The used fungicides alone or combined with K mostly improved tuber quality, especially their low concentrations. The used fungicides mostly doubled starch content in potato tubers. Increase the concentration from half dose to the dose of Acrobat, Ridomil, and Equation inhibited partly the metabolism and translocation of starch to tubers whether they were applied as a single or combined with K. Opposite trends were exhibited by Galbin, and Champion. Combination of the half dose of most fungicides with K increased tubers starch content greatly than their doses as a single. The highest starch content was after spraying the half dose of Acrobat combined with K. On the opposite there were slight decreases in starch by the dose of some fungicides. This decrease could be due to starch utilization in the recorded enhancement for the vegetative growth. The content of potato tuber from N, P and K increased also, after spraying the used fungicides singly or combined with K. The three elements maximum content was with the dose of Ridomil. Nitrate content in potato tubers, in the opposite, decreased when the plants were sprayed by the used fungicides. But combining these fungicides with K enhanced an increase in tuber nitrate content. The increases in nitrate content exceeded slightly the control value under the effect of the dose of each of Galbin and Ridomil combined with K.

The overall effect (OE) indicates that all treatments in the present study have resulted in positive effects ranged between a maximum of 553 with the dose of Galbin and a minimum of 182 with half dose of Champion. The half dose of all of the used fungicides except that of Koruse led to lower OE than their dose. Combination K with each half dose or dose of the fungicides increased the OE greatly. The OE under the combination of K with the half dose of the used fungicides exceeded the OE occurred by their dose as a single. The highest value of OE under the half dose combined with K was by that of Acrobat which was also higher than the OE of all treatments of the used fungicides except the combination of Galbin dose with K.

The actual fungicide effectiveness (AFE) was satisfied for the utilization of the used fungicides in controlling the early blight disease to ensure vigorous vegetative growth and good tubers yield. Application of dose alone had higher effectiveness in comparison with half dose of each

fungicide. Combination of K with half doses led to higher AFE than of the dose for all fungicides, except Ridomil and Equation, but the AFE of their half doses combined with K was slightly lower. Acrobat dose and half dose combined with K led to the highest AFE, with a higher value for the later treatment.

In conclusion, application of K combined with the tested fungicides caused marked increase in potato tubers yield as compared with the control. This is due to the reduction of early blight disease incidence in addition to the enhancement for vegetative growth that was reflected greatly on the tubers crop of the plant. Combined potassium with the used fungicides increased their half recommended doses actual effectiveness to equal or higher than that of their recommended doses. Commercially, the combination of K with the half dose of these fungicides compounds is a new approach for controlling this harmful disease of many economic crops with lower costs. Additionally it is an important way to decrease environmental pollution by these chemical compounds through the decrease in their utilization that reduces their impacts on the human health and environment.

## REFERENCES

Abdel-Ati, Y.Y. (1998). Potato yield and quality as affected by nitrogen and potassium application rates. J. Asgri. Sci. Mansoura Uni., 23:2357-2368.

Abo-Sedra, F.A. and S.A. Shehata (1994). Effect of NK fertilization level and foliar spray with Mn and Mo on growth, yield and chemical composition of potatoes. Zagazig J. Agri. Res., 21:145-156.

Alagapan, P. (1976). Studies on the effect of potassium on the root rot of sun flower cuased by *Rhizoctonia bataticola* (Tanf) Butl. And its chemical control. M. Sc. Thesis, Annamalai Univ. (c.f. Crop Disease Innvative Techniques and Management, Current Trends Crop Disease Management: 27-36, 1994.)

Allen, S.E.; H.M. Grinshaw; J.A. Parkinson and C. Quarmby (1979). Chemical analysis of ecological materials. Black Well Sci. Publ. Oxford London Edinburgh Boston, pp 368.

Ames, B.N. and L.S. Gold (1997). Environmental pollution, pesticides, and the preventation of cancer: misconceptions. J. Fed. Am. Soc. Exp. Biol. 11:1041-1052.

Annon, (2001). Pest. Control program. Ministry of Agric ultra Egypt.

Anthonic, R. S. (1977). Biochemical investigations on the root rot of ground nut (*Archts hypogaeal* L.) caused by *Rhizoctonia bataticola* (Tanf) Butl. And the influence of potassium and calcium nutrition on the host parasite interactions Ph. D., Thesis, Annamalai Univ. (c.f. Crop Disease Innvative Techniques and Management, Current Trends Crop Disease Management: 27-36, 1994.

Ashour, S.A. and S.H. Sarhan (1998). Effect of potassium foliar application on growth and yield of potato (*Solanum tuberosum*, L.), J. Agric. Sci. Mansoura Uni. 23:3991-3998.

Beye, F. (1978). Insecticides from the vegetable kingdom pl. res. Dev., 7; 13-31.

Bwruah, P. and L. Saikia (1989).Potassium nutrition in relation to stem rot incidence in rice . J. Potassium . Res., 5: 121 -124.

Dubey, P.S. and L.P.Mall. (1972). Herbicidal pollutive. Pollen damage by herbicidal vapours. Sc. Cult. 39; 556-558.

Epstein, SS; M. Andreae; H. Jaffec.; S.Joshv; H.folk and N. Natnel. (1967). Carcinogenicity of the herbicide melaic hydrazide. Nature, 512: 1388-1390.

Elhaak, M.A. Ismail, A.A. (2003) Impact of some cupper fungicides on downy mildew disease and some metabolites of cucumber. Bull., Fac., Sci., Assiut Univ., 32:143-154.

Finney , D.L. (1971). Probit analysis, 3rd ed. Cambride university press. 333p.

Fr hlich, G. (1979). Phytopathologie und Pflanzenschutz. VEB Gustav Fisher Verlage, Jena. 295 pp.

Habibullah, V.M. and N.N. Prasad (1976). Effect of potassium on growth and production of pectinolytic and cellylotic enzymes by *Fusarium oxysporum* F. melons. Indian J. Exp. Biol.,:733-734.

Mansour , N. A.; M.E. El Defrawi; A. Toppozada and M. Zeid (1996). Toxicological studies on the Egyptian cotton leaf warm *Spodoptera littoralis* (Boised) . VI. Potentiation and antagonism of orgaophosphorus and carbamate insecticides .J. Econ. Entomol. 49,307-311.

Mohit . Singh ; R.r. Singh ; U. Narain and M. Singh (1997) . Efficacy of different fungicides for control of early blight of potato caused by *Alternaria solani.* Annals of plant protection Sci ., 5:1, 114 -115.

Moran, R. and D. Portath (1980): Chlorophyll determination in intact tissues using N,N-dimethyl formamide. Plant Physiol., 65:478-479.

Moustafa, M.S. and A.A. Ismial (2003). The effect of fungicide application types on the efficacy of fungicides used for control late blight of potato.

Naguib, M.I. (1963): Colorimetric estimation of plant polysaccharides. Zucker, 16:15-18.

Ramasamy , K . (1974). studies on certain biochemical and physiological changes in muskmelon plants as influenced by potassium fertilization and *Fusarium oxysporum ,F. melono* . Msc . (Ag) Thes is Annamalai Univ. , India ( C.F Crop diseases . innovative techniques and Management 4 : 227 -231 ).

Sowant .G. G.; PV . Desai and R.G. Padhiar (1999). Effect of different spacing , fertilizer dose , use of *Trichoderma viride* and different fungicidal formulations on the occurance of early blight disease of tomatoes . Indian J. of Environment and Toxicology , 9 : 2 , 84- 87 .

Shtienberg , D.; D. Blachinsky ; g. Ben . Hador and A. Dinoor ( 1996) . Effects of growing season and fungicide type on the development of *Alternaria solani* and on potayo yield .Plant . Disease , 80 : 9, 994-998.

Sivaprakasam , K.(1994) Management of fungal diseases by plant products. In; crop Disease innovative techniques and Mangement. pp. 107- 11-icalyzin publishers, New Delhi.

Snedecor, G.W. and W.G. Cochran (1973). Statistical methods (6th Eds). Ames, Iowa, USA,: The Iowa State University Press. 305 pp.

Tawfik, A.A. (2001). Potassium and calcium nutrition improves potato production in drip-irrigated sandy soil. African, Crop Sci. J., 9:147-155.

Topps, J.H. and R.L. Wain (1957). Investigation of fungicides. III. The fungitoxicity of salicylanilide and parachloro-anilines. Ann. Appl. Biol., 45:506-511.

Towsend, G.K. and T.W. Heuberger (1943). Methods for estimating losses caused by diseases experiments. Plant Dis. Rept. 27:340-343.

Zein, A.A.; M.A. Ashry; A.E. El-Sherbeni and A.A. Ismail (1990). Fungicidal toxicity and joint fungitoxic action of some pesticides. J. Agri. Res. Tanta Uni., 16:808-817.

Zein, A.A.; F.A.M. Ahmed; M.H. tag EL.Din and J.B.EL. Nagar (2002). Toxicological studies of some pesticides on certain vegetable crops pests .J.Agric. Sci.; MAnsura, Univ., 27 (12): 8679- 8694

## التأثير المشترك لرش البوتاسيوم مع المبيدات الفطرية فى مكافحة مرض النـــدوة المبكرة ونمو وجودة المحصول فى البطاطس

**عبد الوهاب عنتر اسماعيل[١] - البسيونى احمد رضوان[٢] - محمود ابو اليزيد عبد الحق[٣]**

**١- معهد بحوث أمراض النبات**

**٢- قسم بحوث البطاطس معهد بحوث البساتين- مركز البحوث الزراعية- الجيزة**

**٣- قسم النبات كلية العلوم - جامعة طنطا - طنطا - مصر.**

أجريت التجربة الحالية بمحطة البحوث الزراعية بالجميزة محافظة الغربية مصر علـــى مـدى موسمين زراعيين لنبات البطاطس (*Solanum tuberosum*) كنبات عائل لفطـر الألترناريـا سـولانى (*Alternaria solani*) المسببة لمرض اللفحة المبكرة فى البطاطس. اشتملت الدراسة على تجارب معملية وأخرى حقلية. أوضحت النتائج المعملية أن شامبيون Champion أكثره تثبيطا للنمو الفطرى حيث كـان التركيز الذى أدى الى ٥٠% تثبيطا لنمو الفطر ($IC_{50}$) هو ٠,٣٧ جزء فى المليون بينمـا كـان كـورس Koruse أقلها تأثير حيث كانت قيمة $IC_{50}$ ٥,٦٥ جزء فى المليون. ولوحظ أيضا أن البوتاسيوم أعطـى تأثيرا طفيفا مقارنا بالمبيدات الفطرية المستخدمة على نمو الفطر حيث كانت قيمة $IC_{50}$ ٢٠,٩٨ جزء فـى المليون. ومن جية أخرى أظهرت النتائج أن إضافة البوتاسيوم إلى المبيدات الفطرية (مخاليط) أحدث تـأثير محفز أو مضيف علىالنمو الفطرى.

أدت المبيدات الفطرية المستخدمة تحت الظروف الحقلية الى الإقلال مـن حـدة مـرض النـدوة المبكرة فى البطاطس وكانت الجرعة الموصى بها أكثر تأثير من نصف الجرعة الموصى بها لكـل مبيـد. وزادت كفاءة كل من نصف الجرعة الموصى بها والجرعة الموصى بها من المبيدات المستخدمة برش نبـات البطاطس بالبوتاسيوم. كما وأن هذا الرش بالبوتاسيوم مع المبيد أدى الى زيـادة ملحوظـة فـى محصـول البطاطس و ذلك بسبب تقليله لشدة الإصابة بالمرض الى جانب تحفيزه لنمو النبات الخضري ممـا انعكـس على محصول البطاطس.

أدى استخدام البوتاسيوم مع نصف الجرعة الموصى بها المبيد الى زيادة كفاءتيا الـى أو أعلـى من كفاءة الجرعة الموصى بها من المبيد وعلى ذلك فإن استخدام البوتاسيوم مع المبيـدات أدى الـى تقليـل نفقات مكافحة المرض من ناحية ومن ناحية أخرى فإنه يقلل من التلوث البيئي الخطير على صحة الإنسـان والبيئة المحيطة. ومن نتائج هذه الدراسة يمكن توصى بالرش بالبوتاسيوم أثناء استخدام المبيدات الفطريـة لزيادة كفاءتيا فى مكافحة المرض ولزيادة نمو النبات الخضري ومن ثم محصوله.