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~.\(~£.C.\.t\{E.NE.SS~ ~'LQl.'Q&~C.I.'KR~C-\1~~'-.\.~~~~'k \.~~'k~~"\~~ ~~"i ~"i YIELD UNDER FERTILIZED CONDITIONS

Zahir Ahmad Zahir & Muhammad Arshad
Department of Soil Science. University of Agriculture. Faisalabad

Effectiveness of seed inoculation with *Azotobacter* for improving potato yield was assessed in pot and field experiments under optimum fertilizer application (NPK: 250-150-150 and 200-100-100 kg ha⁻¹, respectively). The data obtained from pot experiment revealed that inoculation significantly increased the tuber yield (up to 45.3 %), straw yield (UP to 61.9%) and the number of tubers plant ; (up to 82.4 %) compared with control (fertilizer appl ication alone). Similarly, inoculation was also effective in enhancing the tuber yield (up to 32.3'1<1), straw yield (up to 15.9%) and the number of tubers plant' (up to 50.0%) compared wil1J controt, under field cotuiuions. The single tuber weight gcnerelb) decreased in response to *Azorobacter* inocuknion both in pot fUp to 25.0%) and hcfd (lip 10 23.4%) experiments. *A..-otobaeter* inoculation had JJO signiticnnt cttecs on moisture perceIltage of potato tubers.

Key words: *Azotobacter* inoculation, fertilized conditions, potato yield

INTRODUCTION

Chemical fertilizers have become an integral part of modern agricultural technology as their applications have increased crop yields tremendously. The importance of chemical fertilizers increases manifold in developing countries which arc facing a real population explosion. The situation is rather precarious in Pakistan where the crop yields have become almost static since the last few years in spite of the increasing fertilizer use (Salcem, 19lJ4).

Inoculation with specific microorganisms is a common practice in many parts of the world and *Azotobacter* is one of them which has been widely used as a commercial inoculant. Conclusions have been drawn that seed inoculation of non-legumes with *Azotobacter* increased the yield by about 10%, cereals by 15-30',Y,(Mishustin *et al.*, 1963; Hussain *et al.*, 1985,)987) and potato by 8.5-42.6% (Irnarn and Badawy, 1978: Hussain *et ot..* IlJl)3). When *Azotobacter* inoculation was used in the presence of chemical fertilizers, 5-56 % further increases in yields of different cereal crops (Sanoria and Rao. IlJ75: Rcddy *et al.*, 1977; Hussain *et al.*, *1985*, 1987: Zahir *et al..* 19%),8-30% in potato (Hussain *et al.*, !91J3) and about 50'1, in some other vegetable crops (Kumarswami and Madalgari, 1990) have been reported compared with respective control which received fertilizer application alone.

In view of this, the present studies were undertaken to evaluate the relative effectiveness of different *Azotobacter* cultures for improving growth and yield of potato under fertilized conditions.

MATERIALS AND METHODS

Peat -basd inoculum was prepared by mixing peat with *Aiotobacter* cultures isolated from the University farm soil. Uniform selected tubers were inoculated with the peat-based inoculum just before sowing. In case of control, the tubers were treated with peat that was not inoculated with *Azotobacter* cultures.

Pot Experiment: The inoculated and un inoculated potato tubers (var. Cardinal) were sown in pots (one tuber pot⁻¹) containing 12 kg pori clay loam soil (pHs, 8.00; ECe, 1.90 dS m⁻¹; organic matter, 1.15%; total N, 0.068%; available P, 8.1 mg kg⁻¹ soil: extractable K, 175 mg kg⁻¹ soil). Urea, single super phosphate and sul fate of potash were mixed thoroughly in the soil @ NPK: 250-150-150 kg ha⁻¹, respectively, before filling it into the pots All the treatments were replicated four times in completely randomised design.

Field Experiment: The inoculated and unioculated potato tubers (var. Desiree) were sown in the field (plot size, 240 x 225 cm) on ridges with row x row distance of 75 and plant x plant distance of 22.5 cm in a loam soil (pHs. 7.80; ECe, 1.76 dS m⁻¹: organic matter, O.97'!;; available P, 7.78 mg kg⁻¹ soil and extractable K, 137.00 mg kg⁻¹ soil). Four replications were kept in randomiscd complete *block* design. Fertilizers were applied @ NPK ;WO-I O{)-I 00 kg ha⁻¹, as urea, single super phosphate and sul fate of potash, respectively. Half dose of N and full dose of PK were broadcast and mixed in the soil at the time of seedbed preparation while remaining half N was applied at first earthing up.

Canal water was used for irrigation in both the experiments and earthing up was carried out whenever needed. The data regarding tuber and straw (root + shoot) yield, number of tubers plant⁻¹ and single tuber weight were recorded from both the experiments. and straw and tuber samples were oven dried at 65 ± 5° C to record dry weight of potato straw and to calculate moisture percentage of the tubers. The recorded data were subjected to analysis of variance (Steel and Torrie. 1980) and the means were compared by Duncans' multiple range test (Duncan, 1955).

RESULTS

Pot Experiment: The data given in Fig. I revealed that all the *Azotobacter* cultures significantly increased the tuber (10.6-45.3%) and straw (21.7-61. .9%) yields compared with control (fertilizer application alone). Inoculation with *Azotobacter* culture Z6 resulted in maximum tuber and straw yield. *Azotobacter* culture Z 12 was the least effective in promoting the tuber and straw yield and it helped increase these parameters only by 10.6 and 21.7% compared to control... *Azotobacter* inoculation with all the cultures except Zl) also increased (51)~82.4%) the number of tubers plane' (Fig. I) in comparison with\ontrol. . The increases were significantly greater than con~l where the tubers were inoculated with Z6 and Z7 *culture~otobacter* culture Z6 produced the maximum number of tubers'plant ' (82.4 % more than control) which differed. significantly with control and Z I, Z9 and Z 12 cultures. but non-significantly with other cultures. However, average single tuber weight was less than control (Fig. 1) in case of *Azotobacter* cultures Z6 and Z7. *Azotobacter* inoculation had no significant effect on the moisture percentage of potato tubers (Fig. 1).

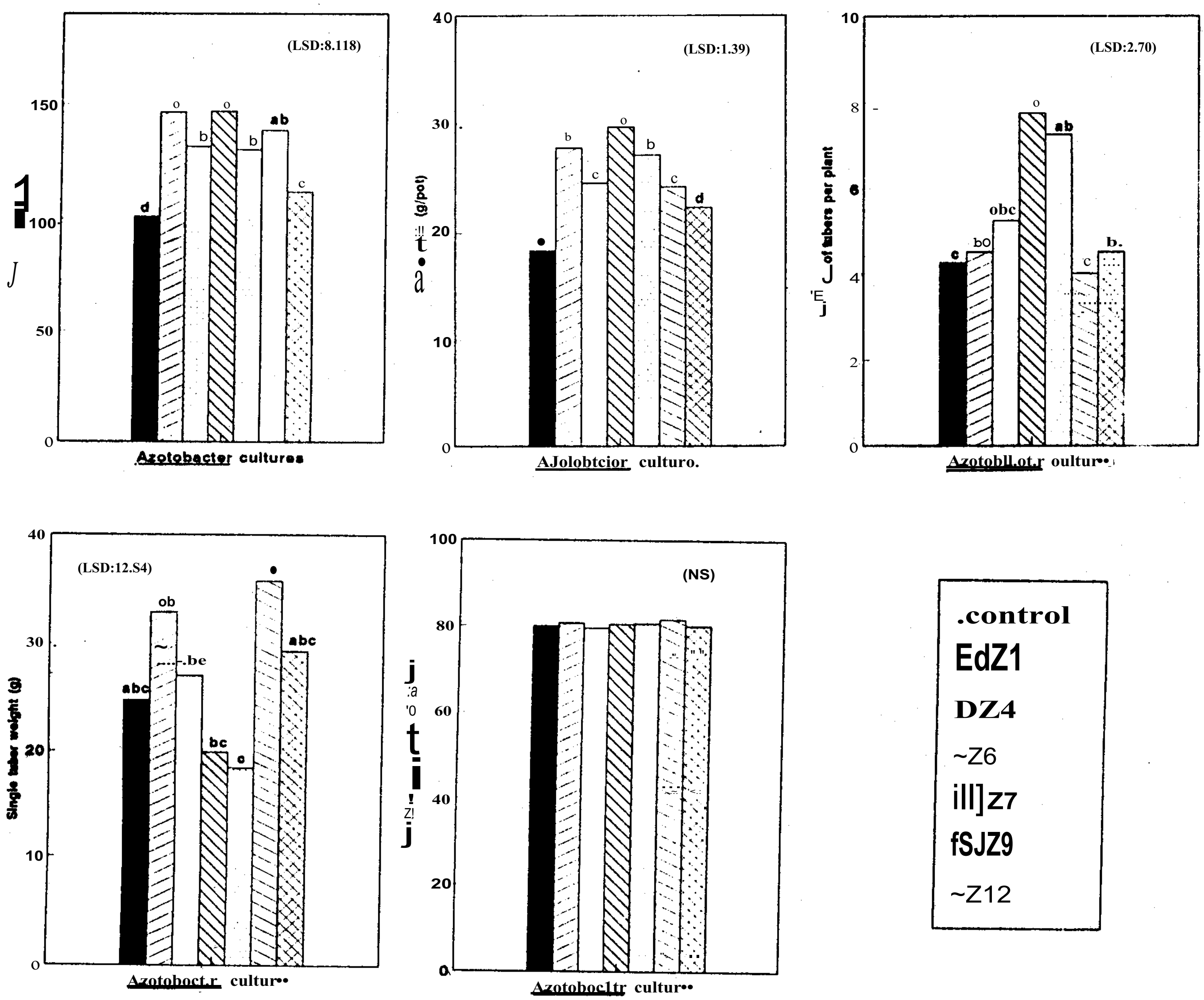

Fig. 1. Effect o! *Azo!c!:ðn~(e"llH)culation* on potato crop under fertilized conditions in pot experiment.

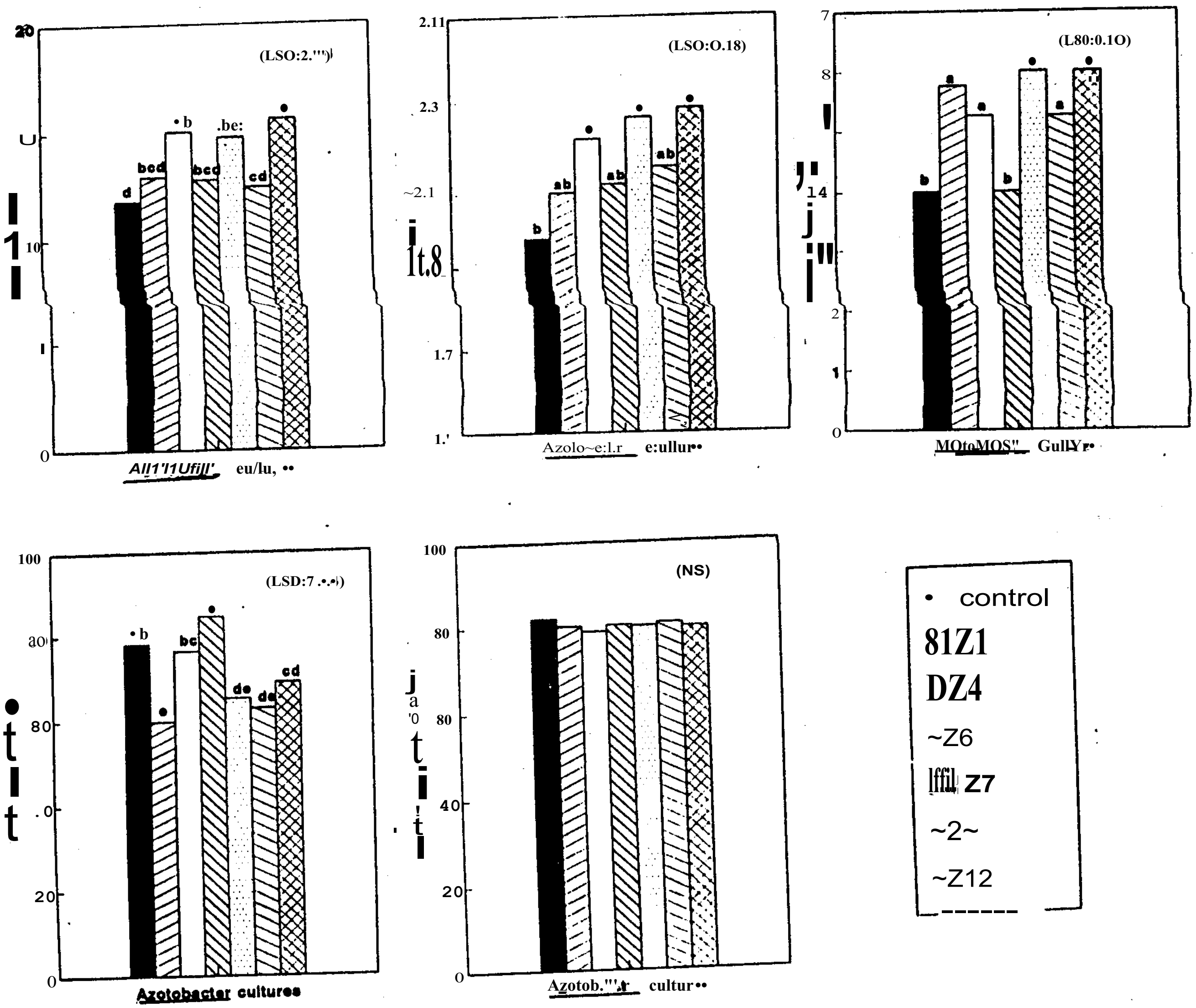

Fig. 2. Effect of *Azotobacter* inoculation on potato **crop under fertilized conditions in field experiment:**

Field Expl'I';illlCIIt: Similar to pot trial, *A::.orobacter* inoculation had a significant effect on the potato yield and its conlributing parameters under fertilized conditions, lnoculariun with *A:,oto!JuCli'l'.,r* cultures Z4, Z7 and Z9 caused siuuific.nu increases in tuber and straw yields (fig, 2) in UJllll';UISI)l\ with conlm! (fertilizer alone), **In** contrast to pol trial, *AzolQbacti'l'.,r* culture Z 12 gave the most promising results and produced maximum tuber *(32.4'!i.* higher than control) and straw (159% higher than control) yield, All *Azotobacter* cultures except Z6 caused significant increase (31.3-50,0';7,;) in the number of tubers plant compared with control (fig.2l. *A:olO!JUCli'l',r* culture *1,7* and Z 12 produced the maximum number of tubers plant ı ('iOO'y"ı more than control) which differed significantly with control and Z6 culture but non-significantly with all other cultures.

Single tuber weight was reduced in response to inoculation with all the *Arotohactcr* cultures except Z6 (Fig. 2). Moisture percentage of potato tubers was not affected significantly by *Azotobacter* inoculation (Fig. 2).

DISCUSSION

Atotobacte: inoculation sigulficantly increased the tuber and straw yields compared with fertilizer alone, both in pot and field experiments. These increases in tuber yield in response to inoculation with *Azotobacter* under fertilized conditions are in agreement with the findings of Hussain *et at.* (1993) who reported IX. I and 2R.'i) 'X, respectively, higher yields in comparison with respective fertilizer application alone. The number of potato tubers plant ı was generally increased by */1::.otolwCler* inoculation both in pot and field experiments, whereas single tuber weight gencrally decreased under field conditions. This could be auributcd to the production of more potato tubers hut of smaller size hy inoculation with *Atotobactcr.*

The beneficial cflcctx of *Azotobacter* were previously auributcd to Nv-Iix.uion (Mishusiin, IS170) but this hypothesis has been rejected now due to di ttcrcnt reasons such as insufficient number or *Azotobacter* in the rhizosphcrc, absence or suitable carbon source, inability of *Azotobacter* to effectively utilize crop rcsiducs, observation of yield increases in Nvrich environment and beneficial effects being produced even by inoculation with non-nitrogen fixin: bacteria (Brown IS182; Hussain *et al.,* 1985, 1987, IS193~ Arshad and Frankcnbcrgcr. lSlSl3). High rate of nitrogen (up to 250 kg ha ı) used in this study might have depressed the functioning of nitrogenase enzyme (Alexander, 1977: Paul and Clark, IS18Sl), Moreover, the soil used was low in organic matter (up to I, IS';{, l, while 454 kg of soil organic matter needs to he oxidized by the *Arotobacter* each year for 2~9 kg or nitrogen tix.uion per acre (Alcx.mdcr, Il)AI), Therefore~ the beneficial effects of *Atotobacter* inoculation under fertilized conditions cannot he auributcd merely to N_2-fixation. The more plausible explanation could he the multiple action mechanism such as N_2 fixation, production of plant growth regulating substances, alteration in microbial balances of soil., suppression of pathogenic microorganisms, mobilization of soil phosphate and production of sidcrophores (Mcshram and Shcndc, IS182 a.b; Zambrc *et a!.,* IS184: Pandcv and Kumar., IS18Sl).

It is also evident from these results that the cultures which produced the hest results in pot experiment (vac Cardinal) were not equally prolific in producing beneficial effects in field experiment (var.. Dcsircc). These differences may he attributed to the variety specific effects of *Aiotobacter* culture (Mchrorra and Lchri, IS170: lmam and Badawy. 197R: Poi and Kabi.)Sl71J). The differences may ;i1so he explained in terms of the production of different types of root exudates ııy di Ifcrcnt varieties (Rovira. IlJ56) which caused changes In bioactiviry of *Atotobacter* cultures. The beneficial eff:CIS to different extent by different *Azotobacter* cultures even in the same variety may be attributed to varying potential of these cultures to produce biologically active substances. Different growth rates and indole acetic acid production by different *Azotobacter* CultUITS (unpublished data) provide sufficient support to this hypothesis.

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