Influence of moisture conservation techniques on *Macrophomina phaseolina* population, dry root rot and yield of clusterbean

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ABSTRACT: Effect of varying levels of soil moisture on *Macrophomina phaseolina* populations and dry root rot intensity in clusterbean (*Cyamopsis tetragonoloba* (L) Taub.) was studied under arid conditions. Mulching with a layer of pearl millet stover (3.5 ton/ha), farmyard manure (10 ton/ha) and low plant population (1.6 lakh/ha), alone or in combination, effectively conserved available soil moisture of varying levels during different stages of crop growth. This resulted in increased population of resident bacteria with a corresponding decrease in sclerotia counts of *M. phaseolina*. Correlations of soil moisture with total bacteria were positive but these factors were negatively correlated with *M. phaseolina*. In path coefficient analysis, the highest negative indirect effects of soil moisture modified the behaviour of antagonistic microorganisms. Enhanced soil moisture and a decrease in *M. phaseolina* population significantly reduced the dry root rot intensity and increased seed yield of clusterbean. However, the interaction of soil moisture gradients with microbial population in regulating the population of *M. phaseolina* at different growth stages of a host crop have not been investigated. Such information could elucidate the relationship between soil moisture factors, *M. phaseolina* populations and mortality due to dry root rot in crops grown under rainfed conditions. This paper reports the effect of moisture conservation techniques on field soil moisture and the role of resident microbial population in influencing the population of *M. phaseolina* and dry root rot intensity in clusterbean (*Cyamopsis tetragonoloba* (L.) Taub.).

MATERIALS AND METHODS

The experiment was conducted at the Central Arid Zone Research Institute, Jodhpur, India during 1984 and 1985. The sandy loam soil of the experimental area contained 91% sand, 5% clay,
4% silt, 0.031% total N and 0.179% organic C. The pH was 8.1, electrical conductivity 0.088 dSm⁻¹, bulk density 1.56 gcm⁻³ and moisture-holding capacity (MHC) 10%.

Eight treatments were arranged in a randomized complete block design with three replications. In each plot, 240 seeds of clusterbean cv FS 277 treated with carbendazim (bavistin 50 WP, BASF Ltd., India) at 2 g kg⁻¹ were sown in six rows. The treatments were (A) control, (B) mulch (pearl millet stover at 3.5 tons ha⁻¹), (C) farmyard manure (FYM) at 10 tons ha⁻¹, (D) low plant population (LPP) maintained at 15 days germination at 160,000 plants ha⁻¹, (E) mulch + FYM (F) mulch + LPP, (G) FYM + LPP and (H) mulch + FYM + LPP.

Seedling emergence were recorded at 15 days after planting (DAP) and the population maintained at 200,000 plants ha⁻¹ (10×50 cm) except in LPP treatments. In each plot, 10 randomly selected plants were tagged to record height, number of cluster and pods, and grain yield. Plants with typical dry root rot symptoms were counted fortnightly to calculate percentage mortality. Grain yield (kg ha⁻¹) was also recorded.

Soil samples were collected from each plot from 3 locations of central two rows at a depth of 0-30 cm at 15-day intervals from sowing to harvest and mixed to form a composite for each replicate. Half of each composite sample was used for the soil moisture determination (gravimetrically), and the other half was air-dried, passed through a 2 mm sieve and processed for the determination of microbial populations. Soil moisture data were calculated to volumetric water content. The population of *M. phaseolina* was determined by wet sieving, serial dilution and use of a selective medium as described by Papavizas and Klag (1975). Colony forming units (CFU) of fungi, bacteria and actinomycetes were estimated by the standard dilution plate method on Martin's Rose Bengal agar, Thornton agar or KenKnight's agar media, respectively.

Correlation coefficient and multiple regression analysis were done for *M. phaseolina* population in relation to variables such as soil moisture, total fungi, total bacteria and total actinomycetes. The direct and indirect effects of the factors influencing survival of *M. phaseolina* populations in the presence of a host crop were calculated by path coefficient analysis (Dewey and Lu, 1959).

**RESULTS AND DISCUSSION**

Quantity of rainfall received was 221 mm in 1984 and 142 mm in 1985. The post-sowing period in 1984 did not favour the development of dry root rot because of an evenly distributed rainfall. In 1985, a 30-day dry spell followed sowing, after which 60 mm of rainfall was received within 3 days. There were no significant rain events thereafter. Thus, the plants suffered from mild moisture stress during the seedling growth and from severe moisture stress at 50 days after planting till harvest. This situation favoured the development of dry root rot. Soil moisture date of year 1985 were correlated with *M. phaseolina* and microbial population.

**Effect of moisture conservation techniques (MCTs) on soil moisture:**

Fortnightly soil moisture data from both cropping seasons revealed that MCTs used alone or in combination effectively retained the soil moisture. The mean soil moisture was maximum (90.7 mm) in the treatment combining all the MCTs. Among individual technique, maximum soil moisture (80.2 mm) was retained in LPP while minimum (66.7 mm) in control plots.

**Effects of soil moisture on *M. phaseolina* and microbial population**

There was a continuous and varied depletion of soil moisture in all the treatments till harvest, except at 45 DAP, when there was an increase due to rainfall. The original population of *M. phaseolina* (32 sclerotia g⁻¹ soil) decreased at 15 DAP and then increased at 30 DAP in most of the treatments. The populations of actinomycetes and bacteria, however, showed a reverse trend, except in
Fig. 1 (A - D) Influence of individual moisture conservation techniques on the soil moisture, total bacteria, total actinomycetes and *Macrophomina phaseolina* population in 1985 at 0 - 30 cm soil depth. Data presented as means of three replications for each treatment. LSD (P = 0.05) for comparison of soil moisture effect, 2.3; for *M. phaseolina* population, 3.8; for total bacteria 1.4; and for total actinomycetes, 0.9. [A- control, B- mulch, C- Farm yard manure (FYM) and D- low plant population (LPP)].
mulch (B) and LPP (D) plots. The increase in soil moisture at 45 DAP favoured the microbial population but reduced the sclerotal counts in all the treatments. At subsequent intervals, M. phaseolina populations tended to increase in different treatments with a progressive decline in soil moisture and bacterial counts. Fluctuations in populations of total fungi had trends similar to those of M. phaseolina population.

The decline in soil moisture and bacterial counts from 60 DAP was accompanied by a linear increase in M. phaseolina (64 sclerotia g⁻¹soil) in the control plots (Fig. 1A). In mulched and FYM-amended plots, bacterial population increased or decreased but actinomycetes increased at 60 DAP (Fig. 1 B-C). Gradual increase in sclerotal counts was estimated till harvest (45 to 46 sclerotia g⁻¹ soil), but the rate of increase was significantly lower than the control. In the plots having low plant population, gradual depletion in soil moisture reduced the rate of increase in M. phaseolina populations at 60 DAP and on subsequent intervals. Thus, 34 sclerotia g⁻¹ soil in the final samples were at par with the original counts (Fig. 1 D).

Soil moisture and bacterial population decreased at 60 DAP and onwards in the treatments combining more than one MCTs. Population of M. phaseolina showed a linear but negligible increase till harvest and remained restricted between 30 and 38 sclerotia g⁻¹ soil (Fig. E-H).

There was a significant positive correlation between soil moisture and total bacteria in LPP + FYM (r = 0.67), LPP + mulch (r = 0.51) and LPP + FYM + mulch (r = 0.84) plots. On the other hand, soil moisture was negatively correlated with M. phaseolina in control (r = -0.52), mulch (r = -0.74), FYM (r = -0.45), LPP + FYM (r = -0.61), LPP + mulch (r = -0.61) and LPP + FYM + mulch (r = -0.58) plots. Total bacteria also were negatively correlated with M. phaseolina in mulch (r = -0.58), LPP (r = -0.52) and FYM + LPP (r = -0.56) plots.

In path coefficient analyses, soil moisture had the highest negative effect on M. phaseolina in control (-0.75), mulch (-0.52), mulch + LPP (-0.68) and mulch + FYM + LPP (-1.05) plots. In LPP and mulch + FYM amended plots, total bacteria had the high negative effects (-0.65 and -0.62, respectively) on M. phaseolina. Total actinomycetes had high negative effects on M. phaseolina in FYM (-0.77) and FYM + LPP (-0.75) plots.

Highest negative indirect effects were calculated for soil moisture with total bacteria in mulch, mulch + LPP and mulch + FYM + LPP plots. Soil moisture and bacteria showed high indirect effects with actinomycetes in FYM amended plots.

**Effect of soil moisture and M. phaseolina population on plant mortality**

Dry root rot mortality was significantly lower in the treatments having MCT in 1985. However, in 1985, only FYM and mulch + FYM + LPP had significant reductions in mortality over the control (Table 1). The mortality was least (3.16%) in the treatment combining all the three MCTs in 1984, but in 1985, a combination of mulch + FYM was superior to it.

Limited soil moisture can be efficiently utilized for the crop growth by using moisture conservation techniques. Conserved soil moisture, in turn, reduced populations of M. phaseolina and dry root rot incidence in clusterbean. In our field experiments, a significant inverse correlation was established between soil moisture and M. phaseolina populations in most of the treatments.

Conserved soil moisture affected increases in native bacterial population with corresponding decrease in total fungi including M. phaseolina. In the presence of adequate soil moisture, antagonistic role of some soil bacteria in reducing the sclerotial population is well documented (Dhingra and Sinclair, 1975). The bacterial activity decreased as soil moisture decreased (Griffin and Quail, 1968). In the present studies, although bacterial population did increase at some sampling intervals (e.g., in LPP, FYM + LPP), but in the absence of adequate soil moisture necessary for their antagonis-
Fig. 1 (E - H) Influence of individual moisture conservation techniques on the soil moisture, total bacteria, total actinomycetes and *Macrophomina phaseolina* population in 1985 at 0 - 30 cm soil depth. Data presented as means of three replications for each treatment. LSD (P = 0.05) for comparison of soil moisture effect, 2.3; for *M. phaseolina* population, 3.8; for total bacteria 1.4; and for total actinomycetes, 0.9. [E- mulch+FYM, F- mulch+LPP, G- FYM+LPP, and H- mulch+FYM+LPP].
Table 1. Effect of moisture conservation techniques on *Macrophomina phaseolina* induced mortality, yield components and grain yield of clusterbean

<table>
<thead>
<tr>
<th>Techniques</th>
<th>Plant mortality (%)</th>
<th>Height (cm)</th>
<th>Clusters (No.)</th>
<th>Pods (No.)</th>
<th>Grain Yield (g plant⁻¹)</th>
<th>Grain Yield (kg ha⁻¹)</th>
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<tr>
<td>Mulch</td>
<td>5.4 (15.8)¹</td>
<td>68</td>
<td>4.1</td>
<td>14.8</td>
<td>3.1</td>
<td>244.7</td>
</tr>
<tr>
<td>FYM</td>
<td>4.3 (11.2)</td>
<td>65</td>
<td>4.7</td>
<td>15.7</td>
<td>3.0</td>
<td>258.1</td>
</tr>
<tr>
<td>LPP</td>
<td>6.7 (15.1)</td>
<td>71</td>
<td>4.0</td>
<td>16.0</td>
<td>3.2</td>
<td>285.1</td>
</tr>
<tr>
<td>Mulch + FYM</td>
<td>5.2 (12.7)</td>
<td>67</td>
<td>4.2</td>
<td>17.1</td>
<td>3.2</td>
<td>301.1</td>
</tr>
<tr>
<td>Mulch + LPP</td>
<td>9.6 (19.0)</td>
<td>62</td>
<td>4.9</td>
<td>20.3</td>
<td>3.2</td>
<td>286.2</td>
</tr>
<tr>
<td>FYM + LPP</td>
<td>6.1 (13.4)</td>
<td>65</td>
<td>5.0</td>
<td>17.4</td>
<td>3.3</td>
<td>263.3</td>
</tr>
<tr>
<td>Mulch + FYM + LPP</td>
<td>3.1 (11.1)</td>
<td>73</td>
<td>5.1</td>
<td>23.4</td>
<td>3.4</td>
<td>369.2</td>
</tr>
<tr>
<td>Control</td>
<td>12.7 (18.2)</td>
<td>55</td>
<td>3.2</td>
<td>12.8</td>
<td>2.3</td>
<td>198.8</td>
</tr>
<tr>
<td>LSD (0.05)</td>
<td>6.9</td>
<td>9</td>
<td>NS²</td>
<td>2.3</td>
<td>1.0</td>
<td>59.8</td>
</tr>
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|                  |                     |             |                |            |                         |                        |
| 1985             |                     |             |                |            |                         |                        |
| Mulch           | 7.9 (16.1)          | 36          | 4.3            | 15.9       | 1.8                     | 136.2                  |
| FYM             | 7.9 (16.3)          | 38          | 5.1            | 13.9       | 1.4                     | 153.9                  |
| LPP             | 5.8 (16.2)          | 34          | 5.0            | 14.5       | 1.5                     | 172.9                  |
| Mulch + FYM     | 10.3 (18.7)         | 33          | 6.0            | 17.5       | 1.5                     | 177.0                  |
| Mulch + LPP     | 8.3 (16.7)          | 34          | 4.9            | 15.3       | 2.3                     | 175.8                  |
| FYM + LPP       | 7.4 (15.7)          | 35          | 8.0            | 17.5       | 2.7                     | 175.8                  |
| Mulch + FYM + LPP | 7.9 (15.8)        | 41          | 8.9            | 20.2       | 3.5                     | 236.6                  |
| Control         | 27.5 (31.3)         | 26          | 2.8            | 9.6        | 1.2                     | 101.1                  |
| LSD (0.05)      | 5.8                 | 7           | 5.3            | 2.2        | 1.3                     | 51.3                   |

¹Arc sin transformations; ²Non significant.

On *M. phaseolina* in many of the promising treatments support this view.

FYM amendment increased microbial population, particularly that of actinomycetes. Increased population and antagonistic activity of actinomycetes and bacteria against *M. phaseolina* in amended soils was reported by Ghaffar *et al.* (1969). Unlike soil bacteria, antagonistic activity of actinomycet-
es was not always hampered at the low soil moisture. Bumbieris and Lloyd (1966) detected lysis of fungal hyphae in a soil too dry for bacterial activity and concluded that actinomycetes were responsible for the lysis in the dry soils. Lodha et al. (1990) also observed that in fairly dry arid soils, actinomycetes reduced the counts of *M. phaseolina*.

Low plant population reduced sclerotial counts and plant mortality of clusterbean in the present study. Severe incidence of charcoal rot in a dense crop of sorghum has been reported by Pande et al. (1989). Wider spacing and the consequent less inter-plant competition, improved the plant vigour to better withstand the fungal infection. The chances of infection also are reduced since mycelia do not travel freely for 1 to 3 mm in natural field soil (Norton, 1953).

The population of *M. phaseolina* reduced by 96 to 99% at 100% MHC in laboratory experiments (Dhingra and Sinclair, 1975). Such sharp decline in field experiments is not tenable. Actual and biologically meaningful data on the survival of *M. phaseolina* sclerotia can only be obtained *in situ* under the prevailing soil conditions and production practices. Fluctuations in soil moisture, and microbial population, adjunct with the presence of a susceptible host offered complex interactions and contribute their might in maintaining the typical host-pathogen balances. Moisture conservation techniques did play a significant role in effectively restricting the multiplication of the *M. phaseolina* sclerotia in the soil, however, expectation of complete elimination of the inoculum from the soil would be unrealistic.

Correlation and multiple regression equations were calculated to ascertain interactive influence of soil moisture and *M. phaseolina* population at each stage on plant mortality. However, significant correlations between *M. phaseolina* population and mortality were established only at the fourth, fifth and sixth stages of sampling; \( r = 0.67, 0.69 \) and 0.66, respectively. The multiple regression equations worked out for these stages were:

\[
Y = -8.85 + 0.36x_1 + 0.46x_2 \quad (R^2 = 0.47) \quad \text{(Stage IV)}
\]

\[
Y = -12.03 + 1.17x_1 + 0.30x_2 \quad (R^2 = 0.63) \quad \text{(Stage V)}
\]

\[
Y = -9.93 + 0.43x_1 + 0.37x_2 \quad (R^2 = 0.49) \quad \text{(Stage VI)}
\]

where \( Y = \text{plant mortality}, x_1 = \text{soil moisture and} \)

\( x_2 = M. \text{phaseolina population.} \)

**Effect of MCTs and plant mortality on yield components and yield**

Low rainfall in 1985 adversely affected all yield components except the number of clusters. In both the years, MCTs significantly improved the yield over the control (Table 1). A combination of all the MCTs gave maximum plant height and maximum number of clusters, pods with higher plant and grain yields. FYM, in combination with LPP or mulch, gave higher seed yield than any other treatments.

Low soil temperature and high actinomycetes population reduced sclerotia of *M. phaseolina* in the absence of a crop (Lodha et al., 1990). The present findings conclusively establish that soil moisture and the bacterial population are the principal factors governing the population of *M. phaseolina* in the presence of a crop. Thus, application of moisture conservation techniques for the efficient utilization of available moisture would also reduce the population of *M. phaseolina* in soil and plant mortality in clusterbean in arid regions.

**REFERENCES**


