Seedbed treatment with direct heat from burning stubble and its effect on seedbed fungi, damping-off, and growth of tomato seedlings

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ABSTRACT

A 1-m^2 seedbed with a history of damping-off was exposed to heat from burning stubble and assayed for soil fungi, damping-off, and growth of tomato seedlings. Seedbed drenched with a formalin-water mixture and an untreated seedbed were also studied. Heat was produced by burning a heap of stubble on the bed two times in two consecutive days. Temperatures of the heated bed were measured during heating at about 0-5 and 5-15 cm depths with a thermocouple fitted to a thermometer. Seedbed soils were assayed for fungi by the soil dilution plate technique and the beds bioassayed two times *in situ* at 4-mn interval with the tomato cultivar, Power. Soil *p*H, nitrogen, phosphorous and potassium concentrations were also determined. Soil temperatures ranging from an average of 55 °C (bottom 5-15 cm) to 70 °C (top 5 cm) were recorded during burning. Heating eradicated pythiaceous fungi and most fungi from the top 15 cm of the seedbed. Untreated seedbed had significantly higher populations of fungi. The effect of heat was comparable to that of formalin. Post-emergence damping-off was 0, 0.65 and 55.88 per cent, respectively, on the heated, formalin-treated and untreated beds. Tomato seedling growth (seedling height, fresh and dry weights) was significantly greater on the heated bed than on the unheated bed. Higher levels of soil *p*H, potassium and phosphorous were associated with the heated seedbed. However, soil nitrogen was unaffected. Based on these results, burning of stubble on seedbeds can be recommended as a non-chemical integrated pest management approach against weeds, damping-off of seedlings, and for enhancing seedbed fertility.

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RÉSUMÉ

AWUAH, R. T.: *Le traitement de semis avec la chaleur directe de chaume brûlant er son effet sur le fongus de semis, le humectage et la croissance de jeunes tomates.* Un semis de 1m^2 ayant une histoire de humectage était exposé à la chaleur de chaume brûlant et mis à l'essai pour le fongus du sol, le humectage et la croissance à venir de jeunes tomates. Pour le but de comparaison un semis trempé de formol: eau (7:1) mélangé et un semis non-traité étaient également étudiés. Chauffage était accompli par le vrûlage d'un tas de chaume sur le semis deux fois pendant deux jours consécutifs. Les températures de semis chauffé étaient prises pendant le chauffage à approximativement 0-5 cm et 5-15 cm de profondeurs avec une thermocouple ajusté au thermomètre. Les sols du semis étaient mis à l'essai pour le fongus pat la technique de plaque de dikution du sol et les semis étaient mis au bio-essai deux fois *in situ* à l'intervale de 4-mn avec la variété du tomate appellée Power. Les niveaux de *p*H du sol, l'azote, la phosphore et le potassium étaient également déterminés. Les températures de sol variant entre un moyen de 55 °C (en bas 5-15 cm) et 70 °C (enhaut 5 cm) étaient réalisées pendant le brûlage Chauffage éradiquait le fongus pythiaceoux et la pludart fongus de 15 cm du haut du semis. Le semis non-traité avait les populations de fongus considérablement plus élevées. L'effet de la chaleur était comparable à celui de formol. Le humectage de post émergence était 0, 0.65 et 55.88 % respectivement sur les semis chauffés, traités de formol et non-traités. La croissance de jeune tomate (taille de jeune tomate, poids de plante fraîche, poids de plante sèche) était considérablement meilleure sur le semis traité de chaleur que sur le semis non-traité. Les niveaux plus élevés de *p*H du sol de potassium et de phosphore étaient associés avec le semis chauffé. L'azote du sol n'était, cependant, pas influencé. D'après ces résultats, le brûlage de chaume sur les semis pourrait être recommandé comme un approche non-chimique intégré de désinsectisation pour lutter contre les mauvaises herbes et le humectage de jeunes tomates et pour eméliorer la fertilité du semis.

Introduction

Tomato (*Lycopersicon esculentum* Mill.) is an important vegetable in Ghana with many uses. Like most vegetables in Ghana, tomato seedlings are raised on seedbeds before transplanting onto field beds. Tomato seeds are not dressed with fungicides, and seedbeds are seldom disinfected; so seedlings are prone to attack by damping-off (Awuah, 1995, 1998), Typically, damping-off attacks the stem of the seedling at the soil level, toppling it over (post-emergence damping-off) (Agrios, 1988). The disease can also attack the seed or the germinating seed or both below the soil, resulting in either seed decay or non-emergence of the seedling (pre-emergence damping-off) (Agrios, 1988). Damping-off is caused primarily by *Pythium* spp. (Hou *et al*., 1999; Roberts *et al*., 1997; Ayub *et al*., 1999), but other fungi such as *Phytophthora*, *Rhizoctonia* (Bucki *et al*., 1988; Gutierrez, Shew & Melton, 1977; Ho *et al*., 1993) and *Fusarium* (Mao *et al*., 1977; Bucki *et al*., 1988; Harender, Bhardway & Sharma, 1997) can also cause the disease.

Soil treatment with heat (Baker & Roistacher, 1957; Harender *et al*., 1997; Chupp & Sherf, 1960) and chemicals (Ayub *et al*., 1999; Csinos *et al*., 1997) as well as seed dressing with suitable fungicides (Walker, 1991; Abdel-Rehim *et al*., 1994; Ho *et al*., 1993) are methods for solving soil-borne seedling problems.

Methods of applying heat *in situ* to seedbeds, using conventional methods, are not feasible in Ghana not only because of lack of facilities, but also because such methods do not fit into the tradition-based farming practised in Ghana. The use of chemicals on seedbeds and for seed dressing are not stressed owing to cost implications, scarcity of suitable soil pesticides, and environmental and health concerns. Thus, other approaches to seedbed disinfestation which conveniently fit into farmers' cultural practices must be explored.

One potential method is to burn stubble on the seedbed. Khrisha Murty & Elias (1969) applied heat by burning paddy husk on tobacco nurseries to control root knot nematodes. Dhrub, Androtra & Singh (1997) also used prescribed burning to control seedling mortality on citrus seedbed.

Although farmers in Ghana sometimes raise seedlings on burnt patches of land, the practice has not been critically investigated in the light of this study. The objective of the study was to treat a tomato seedbed with direct heat from burnt stubble and assess its effect on seedbed fungi, damping-off caused by these fungi, and on growth of tomato seedlings raised on the bed.

Materials and methods

Establishment of seedbeds and treatments

A 1 × 3.5-m plot of land was marked out and the soil thoroughly mixed and worked into a fine tilth. Preliminary *ex situ* bioassay of soil samples collected from the land for damping-off using the tomato cultivar, Power, showed that the disease was a problem on the land. The land was divided into three equal-sized seedbeds (1 m × 1m each), separated from each other by 15-cm thick, 20-cm high sandcrete blocks (Fig. 1 a, b).

One bed was heated by burning on it a heap of stubble consisting of dry stem pieces of elephant grass and *Chromolaena odorata,* and also pieces of miscellaneous woods on two consecutive occasions within 24 h (45-60 min for each). During burning, soil temperatures at about 0-5 and 5-15 cm depths were measured at 15-min interval by pushing aside a portion of the burning stubble and inserting into the soil, a soil thermocouple fitted with a Barnant digital thermocouple thermometer. The second seedbed was completely drenched with a formalin : water (7 : 1) mixture, tightly covered with a polyethylene sheet which was removed after 1 week and the soil turned periodically for 2 weeks with a clean garden fork. The third seedbed received neither heat nor chemical and constituted the untreated control.

Assay of seedbed soils for fungi

Soil samples collected from the heated seedbed were assayed for fungi immediately after the

Fig. 1. Growth of tomato seedlings on heated, formalin-treated and untreated seedbeds. **A**, 7-day-old seedlings shaded with a palm frond shed. Heated, formalin-treated and untreated beds are from left to right; **B**, 14-day-old seedlings on beds. Heated, formalin-treated and untreated beds are from left to right; **C**, 14-day-old seedlings on heated seedbed; **D**, 14-day-old seedlings on formalin-treated seedbed; **E**, 14-day-old seedlings on untreated bed. Poor seedling stand on this bed is due to damping-off.

second heating, together with soils from the untreated bed. Formalin-treated bed was assayed 1 week after treatment when the bed was uncovered. Four replicate soil samples were collected from each seedbed. The moisture contents were determined gravimetrically by oven-drying 10-g samples at 105 ^{o}C to constant weight and the dry soil material calculated. To estimate fungal population, a 2-g soil sample was shaken in 100 ml of sterile water in a 250-ml Erlenmeyer flask. One millilitre of the initial soil-water suspension was serially diluted with 99 ml of sterile water, and 0.5 ml of the final dilution spread on chloramphenicol (500 ppm) potato-dextrose agar plates. Four replicate plates were prepared for each of four soil samples per seedbed. The plates were incubated on a laboratory bench (diffuse sunlight, supplemented with about 6 h fluorescent light; 28 ± 5 ^{o}C) for 5 days. Emerging fungal colonies were identified, counted and the counts expressed as colony-forming units per gram of oven-dry soil.

Bioassay of seedbed for damping-off

Heated and formalin-treated beds were assayed, *in situ*, 3 weeks after treatment together with the untreated bed. With the heated bed, ash left over after burning was completely scraped off before sowing. Each bed was sown with 300 tomato seeds of 90 per cent germination along 18-mm deep, 46-cm long drills, covered with soil and firmed. Four such drills (rows, representing four replicates) were sown per bed. A palm frond shed was raised over the beds for 2 weeks to partially shade the emerging seedlings (Fig. 1a). The beds were drenched with water when necessary to create favourable conditions for damping-off.

From 4 until 14 days after sowing, the number of plants in a row affected by post-emergence damping-off was recorded. Non-germination of seeds during the period was also determined based on knowledge of final seedling stand, total number of seeds sown per row (300), and percent seed germination (90 %). Surviving seedlings were grown for an additional 2 weeks and the final seedling stand (per row) determined. In determining seedling height per row at 2, 3 and 4 weeks, the height of a cluster of seedlings was measured at three points along the row and averaged. The seedlings were also observed for chlorosis and weeds, if any, and noted.

At 4 weeks seedlings were visually assessed for chlorosis, gently uprooted and soil washed off the roots. Fresh and dry weights for all surviving seedlings per the 46-cm long row were determined and, based on the final seedling stand, the average fresh and dry weights per seedling estimated. Dry weight was determined gravimetrically by oven-drying at 80 ^{o}C to constant weight.

To determine the residual effect of heat and the formalin treatments, *in situ* bioassay of the beds for damping-off and seedling growth characteristics was repeated after a 4-month fallow period.

Analysis of seedbed soils

From each bed, soil samples were collected at five locations, bulked and thoroughly mixed together in a polyethylene bag. The soil was analysed for total nitrogen, available phosphorus, exchangeable potassium, and *p*H (1:2.5, soil:water) at the Soil Science Laboratory of the Department of Crop Science, following standard procedure (Anon., 1979).

Results

Temperatures ranging from 55 to 70 ^{o}C were raised with heating, respectively, in the lower 5-15 cm and top 5 cm depth of the seedbed.

Table 1 presents population levels of *Pythium* and *Phytophthora* (pythiaceous fungi), *Rhizopus* and *Mucor* (mucoraceous fungi), and other fungi (*Penicillium*, *Aspergillus*, *Trichoderma*, *Fusarium* spp.) in untreated and treated seedbed soils. Heating the seedbed reduced the populations of pythiaceous, mucoraceous and other fungi, respectively, from 3.6643, 4.4470, 3.322 to 0, 1.6263 and 0 log values CFU g^{-1} dry soil.

TABLE 1

Population of Fungi in Seedbed Soils Before and After Treatment with Heat and Formalin[1]

	Before treatment[2]				*After treatment*[2]			
Seedbed treatment	*Pythiaceous fungi*	*Mucoraceous fungi*	*Other fungi*	*Total fungi*	*Pythiaceous fungi*	*Mucoraceous fungi*	*Other fungi*	*Total fungi*
Direct heating	3.6643	4.4470	3.2220	4.5349	0.0000	1.6263	0.0000	1.6263
Formalin drench	3.5318	4.4332	2.2444	4.5088	0.0000	0.6929	0.0000	1.0071
Untreated	3.7427	4.5802	1.6253	4.6396	3.7231	4.7294	2.2319	4.7715
LSD	NS	NS	NS	NS	0.643	1.501	0.2603	2.335
CV (%)	3.55	2.58	59.88	1.88	25.92	58.38	18.67	55.82

[1]Determination was by the soil dilution plate technique; four replicate soil samples/treatment were plated.
[2]Values are Log (CFU + 1) transformations of the original values (based on per g dry wt of soil). Pythiaceous fungi are *Pythium* and *Phytophthora*; Mucoraceous fungi are *Mucor* and *Rhizopus*.

Populations in the heated bed were not significantly different from values recorded for the formalin drench, but were significantly different from values associated with the untreated seedbed. Weeds were also controlled by heat and formalin.

In the first *in situ* bioassay, non-emergence of seedlings (representing pre-emergence damping-off) was also significantly reduced from 65.75 per cent (untreated seedbed) to 34.44 per cent with the heat, and post-emergence damping-off was completely eliminated with the heat. The effect of heat and formalin drench were not significantly different (Table 2; Fig. 1c-e). When the seedbeds were assayed again after 4 months, seedling pre-emergence damping-off (43.61%) and post-emergence damping-off (14.18 %) were significantly lower on the heated bed than on the untreated and formalin-drenched bed (Table 2).

Tomato seedling heights at 4 weeks averaged 37.5 cm (1st bioassay) and 24.8 cm (2nd bioassay) on the heated bed. These values were

TABLE 2

Damping-off of Tomato on Seedbeds Treated with Heat and Formalin[1]

	Pre-emergence damping-off[2]		*Post-emergence damping-off*[3]	
Seedbed treatment	*1st bioassay*	*2nd bioassay*	*1st bioassay*	*2nd bioassay*
Direct heating	34.44	43.61	0	14.18
Formalin drench	45.74	84.44	0.65	37.05
Untreated	65.75	71.58	55.88	21.9
LSD (0.05)	12.09	8.15	18.16	18.11
CV	17.10	10.31	69.49	45.59

[1] Each value is the mean for four replicate rows per bed. Each row was sown with 300 seeds.
Values were arcsine-transformed before analysis and back-transformed as reported here.
[2] % seedlings that failed to emerge; based on number of seeds sown/row (300), % seed germination of 90 % and final seedling stand/row.
[3] % seedlings that toppled over and died after emergence.

significantly higher than values recorded for the untreated and formalin-drenched seedbeds (Table 3). Fresh and dry weights of seedlings were also significantly highest in the heated seedbed (Table 3). Seedlings on the heated bed were dark-green in contrast with those on the formalin-treated and untreated beds which were chlorotic. Weeds were also absent from the heated and formalin-treated beds.

Seedbed *p*H, phosphorus and potassium contents increased with heating, but N did not (Table 4). Apart from N, these soil characteristics were higher on the heated bed than on the unheated ones.

Discussion

Susceptibility of fungal propagules to heat has been reported by several investigators (Baker &

TABLE 3

Effect of Seedbed Treatments on Growth Parameters of Tomato Seedlings

Seedbed treatment	*Seedling height (cm)*[1]						*Wt of all seedlings per row (g)*[2]				*Wt per seedling (g)*[3]			
	1st bioassay			*2nd bioassay*			*1st bioassay*		*2nd bioassay*		*1st bioassay*		*2nd bioassay*	
	2 wk	*3 wk*	*4 wk*	*2 wk*	*3 wk*	*4 wk*	*FW*	*DW*	*FW*	*DW*	*FW*	*DW*	*FW*	*DW*
Direct heating	13.6	29.7	37.5	7.8	17.0	24.8	972.3	44.7	215.6	19.4	5.5	0.3	1.7	0.2
Formalin drench	10.7	24.2	26.5	4.4	7.3	9.7	337.7	33.2	14.9	1.9	2.3	0.2	0.5	0.1
Untreated	5.5	12.8	18.6	4.5	8.3	12.5	124.4	10.5	44.5	4.7	1.1	0.1	0.7	0.1
LSD	1.5	4.3	5.53	0.9	2.4	5.2	133.8	10.8	55.8	4.3	0.8	0.07	0.4	.04
CV	9.6	12.2	11.6	11.0	15.4	23.3	24.4	22.9	42.7	35.1	21.2	25.1	29.4	29.6

[1] Each value is the mean from four replicate rows of seedlings/bed. In each row, the heights were taken at three equidistant points and averaged. FW = Fresh weight; DW = Dry weight.

[2] Each row length was 46 cm (approx). Values are means from four replicate rows of seedlings at 4 weeks. In the 1st bioassay, 177, 147 and 118 seedlings remained, respectively, on the heated, formalin-treated and untreated beds. In the 2nd bioassay, 132, 27 and 63 seedlings, respectively, remained on the heated, formalin-treated and untreated beds.

[3] Each value is the mean seedling weight from four replicate rows/plot and is based on number of seedlings at 4 weeks.

TABLE 4

Seedbed p*H and Nutrient Levels Before and After Two Seedbed Treatments*

Seedbed treatment	*Before treatment*[1]				*After treatment*[1]			
	p*H*	*N(%)*	*P(ppm)*	*K(ppm)*	p*H*	*N(%)*	*P(ppm)*	*K(ppm)*
Direct heating	5.14	0.25	25.20	50.00	6.41	0.17	37.50	60.00
Formalin drench	5.44	0.20	22.00	45.00	4.84	0.15	23.75	45.00
Untreated	5.94	0.13	28.50	48.50	5.58	0.18	28.5	48.50

[1] Soil *p*H was determined for a 1:2.5 (soil: water mixture). Total N, available P and exchangeable K were determined following standard procedure (Anon., 1979).

Roistacher, 1957; Awuah & Lorbeer, 1991; Filip & Yang-Erve, 1997; Dhrub *et al*., 1977; Bateman *et al*., 1998; Staddon, Duchesne & Trevors, 1998). Baker & Roistacher (1957) reported soil temperatures of 52 °C (30 min) to be effective against *Rhizoctonia*, 46 °C (20-40 min) against *Pythium*, 55 °C (15 min) against *Botrytis*, 57 °C (30 min) against *Fusarium*, 50 °C (30 min) against *Sclerotium rolfsii*, and 50 °C (5 min) against *Sclerotinia*. According to the authors, most plant pathogenic fungi are destroyed by heating soil to 60 °C for 30 min. Soil temperatures were 55 and 70 °C, respectively, in the bottom 5-15 cm and the top 5 cm depth of the seedbed for over 45 min when the bed was subjected to prescribed burning. Not surprisingly, fungi were absent from most soil samples taken from the heated bed. Filip & Yang-Erve (1997) reported that recovery of *Armillaria osotoyae* from wood pieces buried within 8-cm depth of forest soil was significantly reduced with heat from prescribed burning. Lower population levels of *Fusarium culmorum* in burnt soils have also been reported by Bateman *et al*. (1998).

Pythiaceous fungi, *Sclerotium* spp., *Fusarium* spp., and *Rhizoctonia solani* are problematic soil pathogens in Ghana. Their elimination from the seedbed with prescribed burning resulted in control of especially post-emergence damping-off. This finding agrees with that of Dhrub *et al*. (1997) who reported that burning stubble on nursery beds recorded 60 per cent control of citrus seedling mortality caused by *Rhizoctonia* and *Fusarium* spp. Though not studied, it is believed that the soil temperatures recorded for the heated bed would be destructive to root knot nematodes (another nursery problem in Ghana; Awuah, 1995, 1998) as reported by Krishna Murthy & Elias (1969). Because plant pathogenic nematodes have lower lethal temperature thresholds and exposure periods than fungi (Baker & Roistacher, 1957).

In this study, non-emergence of seedlings is considered to be due to pre-emergence damping-off. It was expected that with destruction of fungal pathogens in the seedbed with heat, seedling non-emergence would be considerably reduced if not eliminated. The data collected, therefore, suggest that other factors operating in the heated bed could be responsible for non-emergence of some seedlings. Soil toxicity could be one such factor. The phenomenon is a common problem with heated soils (Wiebe, 1958; Jager, Van Der Boon & Rauw, 1969b; Sonneveld & Voogt, 1973), and is often attributed to high levels of NH_4^+, Mn^{++} and soluble salts (Walker & Thompson, 1949; Wiebe, 1958; Jager *et al*., 1970), the release of which is temperature-dependent (Wiebe, 1958; White, 1971). Further investigations are required to determine if such factors occur in heated seedbed and if so, their effect on seedling non-emergence. If found to be involved in non-emergence of seedlings, heated beds should be allowed to “cure” for over the 2 weeks adopted in this study.

The residual effect of the prescribed burning on post-emergence damping-off was high because only 14.18 per cent of emerging seedlings were affected. This indicates that re-colonisation of the heated soil by damping-off organisms during the 4-month fallow period was low. At 55-70 °C, many soil bacteria, especially the spore formers, survive (Baker & Roistacher, 1957); and these would multiply and enhance the buffering capacity of the heated soil against re-colonisation by soil pathogenic fungi. On the seedbed drenched with formalin, the residual effect of the treatment on damping-off was unexpectedly low. One possible reason could be that the formalin treatment eliminated not only the fungi, but also most if not all bacteria from the soil, allowing for a more rapid re-colonisation of the seedbed by damping-off fungi during the 4-month fallow period.

Tomato seedling growth was enhanced on the heated seedbed. Stimulation in seedling growth cannot be attributed entirely to destruction of soil-borne fungal pathogens by the heat. The release of plant nutrients after applying heat to soil, resulting in increased plant growth, has been reported by several investigators (Jager *et al*., 1969a; Awuah, 1985; Obatolu, 1995; Lessa, Anderson & Moir, 1996). Increases in *p*H, P and K were associated with the heated seedbed in this study, and the tomato seedlings apparently benefited from these. Future studies will focus on whether seedlings from a heated bed would, in the field, outgrow and outyield those from an unheated bed.

Though tomato has been used as the bioassay crop, the study shows that prescribed burning of seedbed can be used for other crops whose seeds require nursing and are susceptible to damping-off. This would be a non-chemical, integrated pest management approach in managing damping-off and weed infestation in seedbeds. The practice would also enhance seedling growth.

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