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Effects of Thiram and Carbendazim Application Rates on Growth and Grain Yield of Chickpea (*Cicer arietinum*) in Kenya

Kibe A. M[1], Kirui K. R[1,*], Wagara I. N[2], Thagana M. W.[3]

[1]Department of Crops, Horticulture and Soils, Egerton University
[2]Department of Biological sciences, Egerton University
[3]Agric. & Sci Tech, Kenyatta University
*Corresponding author: ricksonkirui@hotmail.com

Abstract Fusarium wilt caused by *Fusarium oxysporum* f. sp. *ciceris* is a soil and seed borne disease affecting chickpea (*Cicer arietinum*). It is widely distributed where chickpea is grown and it causes variable yield losses depending on the level of resistance of the genotype and suitability of environmental conditions for disease development. Thiram and carbendazim fungicides are used in most crops as seed dress fungicides against a wide variety of pathogens. The impact of the 0%, 50%, 100% and 150% of the recommended 1.5g fungicide/kg seed rates of these two fungicides on plant height, periodic dry matter and number of pods and grain yield of chickpea was evaluated in the field in a split plot design. Two varieties, Chania 1 which is moderately resistant and Chania 2 which is highly susceptible were grown. Plant height, dry matter and pods per plant were significantly higher in Chania 1 moderately resistant variety and when grown under increasing rates of fungicide application. Increasing fungicide application rates significantly increased grain yield of chickpea. The highest Grain yield of 1.4 t/ha was obtained from 150% (2.25g/kg seed) application of either thiram or carbendazim for MR Chania 1 was grown and treated with either thiram or carbendazim at 150% rate of application. Farmers should grow Chania 1 chickpea variety to minimize use of fungicide application rates to range within 1.5 to 2.25 g fungicide/kg seed and obtain high chickpea growth; yield attributes and grain yields ranging between 1.32 to 1.4 t/ha, respectively.

Keywords: *chickpea, fungicide treatment, growth and yield parameters*

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1. Introduction

Chickpea (*Cicer arietinum* L.) is an important cool season food legume crop mainly grown in dry areas with residual soil moisture and has great agronomic potential for use as food grain, salad, snacks and forage in dry land areas of Kenya [1,2,3]. It is a hardy crop that grows in dry land areas and yields substantially well. Preliminary studies in Naivasha show potential yields of between 1.6 and 2.3 tons of grain per hectare for cultivars ICCV 95423 (Kabuli) and ICCV 97105 (Desi), respectively [4] at varying plant population densities and Nitrogen levels [5]. Serious pests and diseases affecting the chickpea crop at various growth stages however limit its' productivity. Pathogens that affect chickpea crop include fungi, bacteria, viruses and mycoplasma. Fungal pathogens affecting roots, stems, leaves, flowers and pods comprise the most serious group of pathogens of chickpea. The important diseases are Ascochyta blight, Fusarium wilt, Dry root rot, Stunt, Botrytis gray mould, Collar rot, Black root rot, Phytophtora root rot, Pythium root and seed rot [6]. The complex in which soil borne pathogens occur makes isolated control of one pathogen difficult and therefore necessitates combination of host plant resistance together with fungicidal seed treatment strategies and other cultural practices like crop rotation. Chickpea is a relatively new crop in Kenya and is still under yield performance trials and seed bulking in the Rift Valley before adoption by farmers. Several lines that have been found to yield well across several environments need to be evaluated further for drought tolerance and resistance to pests and diseases.

Fusarium wilt causes varying degree of yield losses which can be as high as eighty percent depending on the level of resistance of the genotype. Host plant resistance (resistant genotypes) is the most reliable, environmental friendly, economically affordable to small scale farmers and durable method of management of fusarium wilt and other diseases of chickpea. To ensure durability of resistance genes, host plant resistance (HPR) is used together with other methods of control in an integrated management. Fungicidal seed treatment is frequently used in conjunction with HPR and in this case carbendazim and thiram are chemical fungicides commonly used for control of soil borne pathogens. In Kenya, the impact of these chemicals on growth and yield parameters had not been exhaustively determined. Therefore, a study was conducted to determine the impact of rates of application carbendazim and thiram on plant height, periodic dry matter and number of pods per plant.

The objectives of this study were to determine the effect of carbendazim and thiram rates in important growth parameters and yield attributes of chickpea.

2. Materials and Method

2.1. Evaluation of Fungicides Rates in Control of Fusarium wilt in a Sick Plot

The experiment was set up at KARI Njoro; in a sick plot. One moderately resistant (MR) line (Chania 1) and one highly susceptible (HS) line (Chania 2) was used in the experiment and two fungicides (carbendazim and thiram) at four levels; 0, 50, 100 and 150 % of ICRISAT's recommended dosage (1.5 g/kg seed) of each fungicide. The experimental design was split-plot replicated three times in two seasons. The main plot factors were the two lines of chickpea (ICCV 97105/Chania 1 and ICCV 92944/Chania 2) while the sub plot factors were the two fungicides (Ft and Fc) thiram and carbendazim both at three rates of 50, 100 and 150 %. There was one sub plot of control (0 %) in each main plot; which was not treated with any fungicide. This gave a total of seven treatment combinations per main plot, fourteen treatments per replicate and forty-two sub plots per season. Weekly scoring for Fusarium wilt incidence was done on all treatment plots and the experiment was repeated in another season. A population of 250,000 plants per Ha was achieved at a spacing of 10cm × 40 cm.

3. Results and Discussion

3.1. Effect of Variety and Thiram or Carbendazim on Chickpea Plant Height

3.1.1. Effect of Variety on Plant Height

There were significant ($P \leq 0.05$) differences in the plant height (PH) (Table 1) were observed between the two varieties. At 30 DAS, Chania 1 had a height of 10.8cm while Chania 2 had 10.1cm in season I. In season II, Chania 1 had 11.1cm while Chania 2 had 10.1cm at 30 DAS. At 60 DAS, Chania 1 had plant height (PH) 24.3cm while Chania 2 had 22.3cm (Table 1). The same trend was observed in season II, with Chania 1 obtaining PH of 24.4cm while Chania 2 had 22.8cm. At 90 DAS, Chania 1 had plant height of 28.4cm while Chania 2 had 26.2cm in season I. In season II, Chania 1 had 28.7cm while Chania 2 had 26.3cm. The differences between the two varieties at 90 DAS in terms of PH were significant (Table 1). At 120 DAS, Chania 1 had a PH of 32.3cm while Chania 2 had 30.0cm in season I. In season II, Chania 1 had 32.7cm while Chania 2 had 30.19cm. The difference between the two varieties was significant ($P \leq 0.05$) (Table 1). Moderately resistant Chania 1 had higher plant height across all growth stages in contrast with HS Chania 2, across all growth stages. Table 6 shows a high positive correlation of 0.92 between grain yield and plant height. It is possible to infer that MR variety Chania 1 would yield more grain as compared to HS Chania 2 as a result of better plant height which led to higher dry matter (Table 2) and this in turn was partitioned to grain yield. Genetic resistance of a variety reduces the negative impacts of that pathogen on that variety. Maitlo *et al*. [7] reported in other studies that a healthy crop results from management of *Fusarium oxysporum* f. sp. *ciceris* (through fungicides) and had higher shoot length. Due to the vascular nature of the pathogen, it could be inferred that HS Chania 2 was affected by the pathogen, which could have resulted in blockage of its xylem vessels, thereby leading to reduced plant vigor and subsequently low plant height. This is supported by Khan *et al*. [8] who reported stunting in infected chickpea plants.

3.1.2. Effect of Fungicide Treatment on Plant Height

Plants treated with fungicide were significantly taller in height to the control treatment at all growth stages (Table 1). At 30 DAS, control treatment had lower plant height (PH) of 9.3cm and 9.1cm for seasons I and II, respectively. Treatment with thiram or carbendazim at the rates of 50% to 150% rates gave plant height values in the range of 10.1 to 11.3cm which were higher than the control. At 60 DAS, control treatment had significantly ($P \leq 0.05$) lower PH of 20.0cm and 20.1cm for season I and II, respectively. Treatment with either thiram or carbendazim at 50% gave PH values of 21.5cm and 21.6cm in season I, respectively while in season II, 22.5cm was observed for either of thiram and carbendazim. Treatment with 100% of either thiram or carbendazim gave PH of 24.3cm and 24.1cm, respectively in season I at 60 DAS. The highest PH was obtained by treating chickpea with either thiram or carbendazim at 150% which yielded 25.7cm and 26.3cm, respectively in season I, while in season two, 25.7cm and 25.8cm was obtained for the two fungicides, respectively (Table 1). At 90 DAS, significantly ($P \leq 0.05$) low plant height was observed in the control treatment giving PH of 23.1cm and 22.6 cm for Season I and II, respectively. The highest PH 90 DAS was obtained by treating with thiram or carbendazim at 150% with PH of 30.5cm and 30.8cm, respectively (Table 1). The results of this study are in agreement with other studies which found that fungicide treatments increased plant height as compared to the control [7,8]. Khan *et al*. [8] reported that phytotoxins released by the pathogen induce leaf wilting, chlorosis and sometimes stunting.

Muhammad [9] found a direct correlation between wilt severity and inoculum density. It can be inferred that fungicidal seed treatment inhibits seed or soil borne pathogens creating a rhizosphere free from biotic stress of the pathogen and this could result in vigorous seedlings. At 120 DAS control treatments had significantly ($P \leq 0.05$) low PH of 25.1cm and 24.7cm for seasons I and II, respectively (Table 1). Significantly higher PH was obtained by treating chickpea with either thiram or carbendazim at 100% or 150% with PH values in the range of 32.7cm to 35.5cm 120 DAS (Table 1). No interactions between genotype and fungicide rate were observed. Table 6 shows a positive correlation between plant height and grain yield. According to Mallu *et al*. [16]

the correlation between plant height and dry matter led to more dry matter partitioning into grain yield.

3.1.3. Effect of Variety on Dry Matter Yield of Chickpea

Chickpea DM accumulation followed a sigmoid curve, showing an initial lag phase between sowing and 55 DAS (Figure 1). After the 55th DAS, rapid growth phase followed up to 90th DAS after which the rate of DM production declined as the crop approached maturity. Higher dry matter accumulation depends primarily on the genotype potential in terms of production and pest resistance and secondly on the management practices. From the models (Figure 1), it is possible to design management practices (like fertilization, disease management aspects etc.) in order to gain higher DM in the two chickpea varieties used. Moderately resistant Chania 1 had high DM (Table 2) due to its' nature to resist wilt as compared to HS Chania 2. Correlation of yield attributes showed a negative correlation between DM and wilt incidence of -0.95 at 45 DAS and -0.83 at 60 DAS (Table 6). This means that higher incidences of wilt observed would result in lower dry matter in chickpea. Significant difference in dry matter between the two varieties was visible at 60 DAS, with Chania 2 yielding 2.4 g/plant and Chania 1 yielding 2.8 g/plant in season I (Table 2).

During season II, Chania 2 had 2.5 g/plant DM yield while Chania 1 had 2.8 g/plant at 60 DAS (Table 9). At 90 DAS, Chania 1 had 7.8 g/plant DM yield in season I and II, while Chania 2 had 7.6 g/plant in season I and II. At 120 DAS, DM yield of 11.1 g/plant and 10.8 g/plant were observed in Chania 1 and Chania 2, respectively in season I. In season II, 11.2 g/plant and 10.9 g/plant DM yield were observed for Chania 1 and Chania 2, respectively. It was observed that MR Chania 1 had significantly ($P \leq 0.05$) higher DM yield as compared to HS Chania 2, which was evident from the 60th DAS onwards (Table 2). Higher incidences of wilt in chickpea have been reported to result in up to 100% yield loss under ideal conditions [10]. In highly susceptible (HS) Chania 2, lower DM values were observed because of higher wilt incidence. Negative correlation between Fusarium wilt incidence and DM yield was observed, with high correlation coefficients, r of -0.95 and -0.83 at 45 DAS and 60 DAS, respectively (Table 6). From this negative correlation it can be inferred that if higher wilt incidences are observed in the field at 45 DAS and 60 DAS, lower DM yields of chickpea would be experienced. This observation was in agreement with Haware and Nene, (1980) [17] who reported that early wilting caused more damage as compared to late wilting in chickpea. Further, management of early wilting would be required to avoid economic damage especially in susceptible genotypes. The negative correlation between wilt and DM could also explain the variation in terms of DM yield observed between the two varieties, MR Chania 1 and HS Chania 2 as Chania 1 had low wilt incidence as compared to Chania 2. The highest dry matter was realized with variety Chania I (97105) at 11.1 g/plant and 11.2 g/plant for season I and II, respectively, at 120 DAS (Table 2).

Table 1. Effect of thiram or carbendazim rates on periodic plant height of two chickpea varieties

Treatment	Height 30_I	Height 30_II	Height 60_I	Height 60_II	Height 90_I	Height 90_II	Height 120_I	Height 120_II
92944	10.09 a	10.14 a	22.38 a	22.86 a	26.24 a	26.33 a	30.05 a	30.19 a
97105	10.85 b	11.14 b	24.38 b	24.43 b	28.43 b	28.71 b	32.38 b	32.76 b
LSD	0.73	0.71	0.35	1.28	0.73	0.2	0.82	0.35
C.V	2.0	1.9	0.4	1.5	0.8	0.2	0.7	0.3
Control	9.33 a	9.17 a	20.00 a	20.17 a	23.17 a	22.67 a	25.17 a	24.67 a
$Thiram_{50}$	10.50bc	10.67 b	21.50 b	22.50 b	25.50 b	25.50 b	29.00 b	29.33 b
$Thiram_{100}$	10.50bc	10.50 b	24.33 c	24.50 c	28.33 c	28.50 c	32.67 c	33.00 c
$Thiram_{150}$	11.33c	11.50 b	25.67 d	25.67 c	30.00 c	30.50 de	35.17 d	35.50 d
$Carbendazim_{50}$	10.17 ab	10.67 b	21.67 b	22.50 b	25.50 b	25.83 b	29.00 b	29.33 b
$Carbendazim_{100}$	10.50bc	10.67 b	24.17 c	24.33 c	28.33 c	28.83 cd	33.00 c	33.33 c
$Carbendazim_{150}$	11.00bc	11.33 b	26.33 d	25.83 c	30.50 c	30.83 e	34.50 cd	35.17 d
LSD	0.65	0.77	0.78	0.96	1.31	1.18	1.15	1.07
C.V	5.3	6.1	2.8	3.4	4.1	3.6	3.1	2.9

Means followed by the same letter(s) in the same column are not significantly different at P≤ 0.05 using LSD.

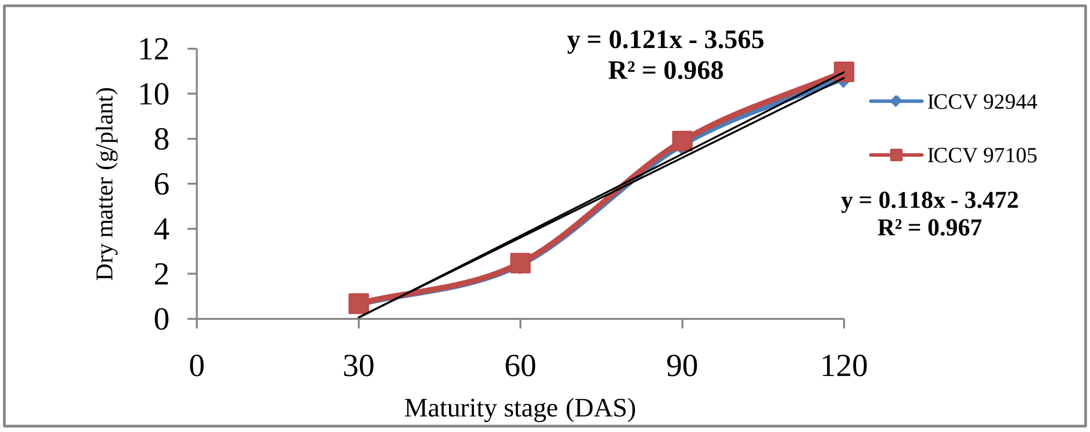

Figure 1. Dry matter accumulation in two chickpea lines

Table 2. Effect of variety, thiram or carbendazim fungicide rates on periodic dry matter of chickpea

Treatments	30 DAS	30 (SII) DAS	60 DAS	60 (S II) DAS	90 DAS	90 (SII)DAS	120 DAS	120 (SII)DAS
Chania 2	0.66 a	0.67 a	2.46 a	2.57 a	7.61 a	7.61 a	10.89 a	10.92 a
Chania 1	0.67 a	0.67 a	2.80 b	2.84 b	7.88 b	7.89 b	11.15 b	11.29 b
LSD	0.01	0.018	0.02	0.03	0.02	0.02	0.04	0.03
C.V	0.3	0.4	0.3	0.3	0.1	0.1	0.1	0.1
Control	0.64 a	0.65 a	2.30 a	2.31 a	7.45 a	7.46 a	10.25 a	10.27 a
$Thiram_{50\%}$	0.66 b	0.66 b	2.44 b	2.49 b	7.61 b	7.61 b	10.37 b	10.59 b
$Thiram_{100\%}$	0.67 c	0.67 b	2.61 c	2.76 c	7.76 c	7.77 c	11.38 c	11.38 c
$Thiram_{150\%}$	0.68 c	0.68 b c	3.03 d	3.05 d	8.02 d	8.03 d	11.72 d	11.78 d
$Carbendazim_{50\%}$	0.66 b	0.67 b	2.43 b	2.49 b	7.60 b	7.61 b	10.37 b	10.59 b
$Carbendazim_{100\%}$	0.67 c	0.68c	2.60 c	2.77 c	7.73 c	7.76 c	11.38 c	11.38 c
$Carbendazim_{150\%}$	0.68 c	0.68 c	3.03 d	3.05 d	8.01 d	8.02 d	11.71 d	11.78 d
LSD	0.01	0.01	0.03	0.02	0.02	0.03	0.05	0.03
C.V	1.1	1.1	0.8	0.7	0.3	0.3	0.3	0.2

* Means followed by the same letter(s) in the same column are not significantly different at P=0.05 using LSD.

3.1.4. Effect of Thiram and Carbendazim Rates on DM Yield of Chickpea

Chickpea dry matter was significantly low in plots under control fungicide treatment on both seasons, across all growth stages. The highest dry matter was observed in 150% rate of either thiram or carbendazim, with dry matter yield ranging from 0.7 g/plant to 11. 8 g/plant across the growth stages (Table 2). The least dry matter ranging from 0.6 to 10.3 g/plant was observed under control treatment (Table 2) across all growth stages. No significant differences were observed between thiram or carbendazim at all growth stages, except between the rates within a fungicide type. It was observed that application of fungicide increased the DM yield of chickpea from a range of 5.9% (at 30 DAS) up to 14.6% (at 120 DAS). The best treatments rate was 150% irrespective of the fungicide used (thiram or carbendazim). This was followed by 100% rate of either thiram or carbendazim. Previous studies found that carbendazim and thiram were effective in reducing wilt incidence and increasing yield [11], while De *et al.* [12] found that coating seeds with carbendazim was more effective in reducing wilt and resulted in yield of chickpea. Other studies have also found that plants protected from the pathogen through chemical seed dress and or genetic resistance had improved yield [7]. Singh *et al.* [13] also reported highest seed germination with carbendazim. This high germination could affect plant population and hence dry matter.

3.2. Interaction of Thiram or Carbendazim and Variety on Periodic Dry Matter

Significant ($P \leq 0.05$) interactions were observed between the treatments and varieties at 60, 90 and 120 DAS (Table 3). The least DM was observed in Chania 2 with control treatment, across all growth stages, with values ranging from 2.1 g/plant at 60 DAS to 10.1 g/plant at 120 DAS. All fungicide treatments of 50%, 100% and 150% had significantly ($P \leq 0.05$) higher DM yield than the control (0%).

The least DM was observed in Chania 2, under control, with DM of 2.1 g/plant and 2.2 for seasons I and II, respectively 60 DAS. At 50% thiram or carbendazim treatment significantly higher DM of 2.3 g/plant was realized in season I and II for both fungicides (Table 3). Treatment of Chania 2 with either thiram or carbendazim at 100% resulted in significant higher DM yield of 2.4 g/plant and 2.3 g/plant, respectively, in season I which was higher than either fungicide at 50% in season I with Chania 2 60 DAS. Chania 1 under control treatment had a significantly ($P \leq 0.05$) higher DM yield of 2.4 g/plant than Chania 2 under either thiram or carbendazim at 100% (Table 3) in season I. In season II, 2.4 g/plant DM was observed in Chania 1 under control treatments which was significantly ($P \leq 0.05$) lower to Chania 2 and either thiram or carbendazim at 100% treatments which had 2.6 g/plant 60 DAS. This suggests an environmental influence on Chania 1 during season II which might have resulted in slightly higher Fusarium wilt incidences, hence the low yield. There was a significant ($P \leq 0.01$) negative correlation; -0.95 between Fusarium wilt incidence at 45 DAS and DM 120 DAS (Table 6). Previous studies reported that treatment of seed with fungicides significantly checks wilt incidence and enhances plant growth and yield [7]. Kamdi *et al.* [11] found that seed treatment with carbendazim and thiram resulted in increased germination, reduced wilt and increased yield. Muhammad [9] reported a direct correlation between inoculum density and wilt severity in chickpea. Fungicide treatment reduces the amount of inoculum in the rhizosphere and these results in a healthy crop which explains the observed increase in dry matter with increase in fungicide rate. In both seasons I and II, the highest DM was realized between the interaction of Chania 1 with either thiram or carbendazim at 150% rate, yielding over 3.1 g/plant DM yield for either fungicide combination in both seasons 60 DAS. The next best combination was between Chania 2 and 150% of either thiram or carbendazim yielding DM of 2.9 g/plant (Table 3) 60 DAS. From these results it can be inferred that at 60 DAS, MR Chania 1 yielded more DM with comparatively less fungicides than HS Chania 2. The results are linked to the wilt incidence observed in Chania 1 and 2. High wilt incidence led to low yield due to unhealthy plants whose vascular systems had been invaded by the pathogen. Khan *et al.* [8] reported the production of phytotoxins by the wilt pathogen which led to chlorosis in affected chickpea.

Chlorophyll content determines the amount of dry matter through photosynthesis. Effective management of Fusarium wilt using fungicide treatments and resistant varieties therefore led to increased dry matter as less pathogen invasion occurred in fungicide treated chickpea compared to the control. Also, it was observed that combination of genetic resistance by choice of resistant variety with fungicide treatment was effective in controlling Fusarium wilt and improving yield. Maitlo *et al*. [7] reported yield increase with increasing fungicide rates.

3.3. Interaction Effects between Thiram or Carbendazim and Variety on DM at 90 DAS

Significant ($P \leq 0.05$) interactions between varieties and fungicide treatments occurred on DM at the 90 DAS. Higher DM yield values in the range of 7.8–7.9 g/plant were observed when Chania 1 interacted with 150% of either thiram or carbendazim (Table 3). The least DM yield was obtained with Chania 2 under control treatment with DM yield of 7.3 g/plant for season I and II, 90 DAS. This was followed by the combination of Chania 2 with either 50% of thiram or carbendazim, resulting in DM yield of 7.4 g/plant in season I and II. Chania 1 combination with control treatment was the next best, in both seasons I and II, with DM yield of 7.5 g/plant in both season I and II. Chania 1 interacted significantly with thiram or carbendazim at 100% to give DM yield which was equivalent to Chania 2 yield under thiram or carbendazim at 150% (Table 3) in both seasons. It can be inferred that to achieve a similar yield in Chania 2, significantly higher (+50%) application of thiram or carbendazim is necessary to achieve the same yield as MR Chania 1. The highest DM yield was obtained in the interaction between Chania 1 and either thiram or carbendazim at 150% giving 8.1 g/plant in season I and II.

3.4. Interaction Effects between Thiram or Carbendazim and Variety on DM at 120 DAS

The highest DM yield 120 DAS was obtained in Chania 1 treated with either thiram or carbendazim at 150%, yielding DM of 11.9 g/plant in season I and II for both fungicides (Table 3). Chania 2 under thiram or carbendazim at 150% resulted in DM yield of 11.5 g/plant for both fungicides in season I and 11.6 g/plant for both fungicides in season II. The least DM yield was obtained with Chania 2 under control treatment, giving DM yield of 10.1 g/plant for seasons I and II. Treatment of Chania 2 with 100% thiram or carbendazim resulted in DM yield of 11.3 g/plant in season I and 11.1 g/plant in season II for both fungicides (Table 3). DM yield of Chania 2 at 100% fungicide was significantly ($P \leq 0.05$) higher than treatment with 50% of either fungicide, but lower than the yield of Chania 1 under 100% rate of thiram or carbendazim. Chania 1 with 100% treatment of thiram or carbendazim resulted in 11.4 g/plant DM in season I and 11.6 g/plant in season II for both fungicides MR Chania 1 had significantly higher yield than Chania 2 under control treatment. Treatment of MR Chania 1 with either fungicide resulted in higher DM yield as compared to treatment to HS Chania 2, across all treatment rates (50%, 100% and 150%). It is therefore recommended that farmers adopt MR Chania 1 genotype as opposed to HS Chania 2 to reduce fungicide treatment rates and realize higher DM yields. Combination of resistance with fungicide treatment was shown to lead to increased DM yield as the crop had better health hence these observations. Based on the vascular nature of the pathogen, invasion of xylem tissues deprives the plant of water uptake which affects other processes like photosynthesis and nutrient mineral absorption. Padwick [14] reported that some plants may look apparently healthy while they have been invaded by the pathogen. In severe cases, the pathogen produces phytotoxins which causes wilting and leaf burning [8]. It was observed that MR Chania 1 was able to yield more DM with lower fungicide treatment as compared to the HS Chania 2. Studies on the effect of fungicide on yield of soybean showed that the yield increase was more related to the disease control aspect of the fungicide that led to a healthy crop yielding more [15]. This study observed that combining resistance with fungicide treatment led to increasing yield which could be attributed to reduced wilt incidence. Mallu *et al.* [16] reported a positive and significant correlation between biomass and grain yield. Management practice that enhances dry matter accumulation therefore leads to higher grain yield. These include management options like treatment of chickpea with fungicides to control wilt. Fusarium wilt has been reported to result in reduced chlorophyll content in chickpea [8] through the production of phytotoxins that can cause leaf wilting, chlorosis or complete plant wilting depending on the race of the pathogen. This way, wilt incidence leads to decline in dry matter of chickpea by affecting processes of photosynthesis and water uptake by blocking xylem vessels.

Table 3. Effects of interaction between fungicide rates and variety on periodic dry matter

	60 DAS_1		60 DAS_II		90 DAS_I		90 DAS_II		120 DAS_I		120 DAS_II	
Treatment	92944	97105	92944	97105	92944	97105	92944	97105	92944	97105	92944	97105
Control	2.18a	2.42d	2.21a	2.41c	7.32a	7.57c	7.35a	7.57c	10.13a	10.37c	10.12a	10.42b
$Thiram_{50}$	2.29b	2.58e	2.30b	2.68d	7.45b	7.76e	7.45b	7.76d	10.25b	10.49d	10.45b	10.71c
$Thiram_{100}$	2.36c	2.85f	2.66d	2.85e	7.62d	7.88f	7.61c	7.91e	11.31e	11.44f	11.10d	11.65f
$Thiram_{150}$	2.87f	3.18g	2.91f	3.18g	7.91f	8.12g	7.92e	8.14f	11.52g	11.91h	11.61f	11.94g
$Carbendazim_{50}$	2.28b	2.57e	2.30b	2.67d	7.44b	7.76e	7.45b	7.76d	10.24b	10.49d	10.45b	10.71c
$Carbendazim_{100}$	2.34c	2.85f	2.67d	2.85e	7.58c	7.88f	7.60c	7.92e	11.30e	11.44f	11.09d	11.65f
$Carbendazim_{150}$	2.87f	3.17g	2.91f	3.19g	7.89f	8.13g	7.89e	8.15f	11.52g	11.90h	11.61f	11.94g
LSD	0.034		0.034		0.034		0.039		0.062		0.041	

Means followed by the same letter(s) in the same column are not significantly different at $P \leq 0.05$ using LSD.

Catherine and Palle. [15] observed that the effect of fungicide on yield of soybean was more related to the disease control aspect of the fungicide, that subsequently led to a healthy crop yielding more. The same can be said with our study in the sense that combining resistance with a bit of fungicide treatment generally led to increasing yield as the wilt incidence is reduced. These results are in agreement with Kamdi *et al.*, [11] who found that carbendazim and thiram were effective in reducing wilt incidence and increasing yield. De *et al.*, [12] found that coating seeds with carbendazim was more effective in reducing wilt and resulted in yield of chickpea increasing in the range of 25.9 to 42.6%.

3.5. Effect of Variety and Fungicide Treatments on Yield Parameters of Chickpea

3.5.1. Effect of Variety and Fungicide Treatments on Number of Pods Per Plant

Significant ($P \leq 0.05$) differences in the number of pods per plant were observed between the two varieties. Chania 2 had 114.1 while Chania 1 had 123.4 pods/ plant (Table 4). Pods per plant had a high positive correlation (r) of 0.93 to grain yield (Table 6). These results were in agreement with Mallu *et al*. [16] who found a positive relationship between number of pod per plant and grain yield. Significantly low number of pods/plant of 101.8 was observed under control treatment. Treatment of chickpea with 100% of either thiram or carbendazim gave 122.7 and 123 number of pods/plant, respectively (Table 4). The highest number of pods per plant was obtained when either thiram or carbendazim was used at 150% recommended active ingredient, which gave 128.3 and 128.1 number of pods per plant, for thiram and carbendazim, respectively (Table 4). Number of pods per plant was positively correlated to both DM and grain yield with correlation coefficients of 0.87 and 0.93, respectively (Table 6). This means that for a farmer to achieve high yield (DM or grain yield), it is necessary; one to choose a variety like Chania 1 which had significantly ($P \leq 0.05$) higher pods /plant of 123.4, and two, adopt a wilt management plan of 150% application which also gave the highest number of pods per plant at 128.3 (Table 4).

3.5.2. Effect of Variety and Fungicide Treatments on 100 Seed Weight and Harvest Index

Significant ($P \leq 0.05$) differences between varieties were observed with Chania 1 having 24.2 g/100 seeds, while Chania 2 had 19.7 g/100 seeds (Table 4). Control treatment had significantly low seed weight at 20.3 g/100 seeds. Treatment of chickpea with either thiram or carbendazim at 50% gave seed weight of 21.2 g/100 seeds and 21.3 g/100 seed, respectively, which were significantly higher than the control treatment (Table 4). Seed treatment with either thiram or carbendazim at 100% gave test weight of 22.3 g/100 seeds. Treatment of chickpea with 150% of either thiram or carbendazim gave significantly higher test weight of 23.1 g/100 seed for both fungicides. Fusarium wilt has been shown to affect the seed weight resulting in lighter and shriveled seeds of dull colour [17]. As fungicide rate was increased, inoculum density was reduced because of the negative effect of fungicide. This led to a healthy plant and hence better seed weight which explains the variation observed in the seed weight. Muhammad [9] reported a direct correlation between wilt severity and inoculum density.

3.5.3. Effects of Variety and Fungicide Treatments on Harvest Index

Results on harvest index (H.I) showed significant difference ($P \leq 0.05$) between varieties Chania 1 and Chania 2, with 48.1% for Chania 1 and 45.6% for Chania 2 (Table 4). The higher harvest index in Chania 1 could be a result of higher DM and grain yield as compared to Chania 2. Fungicide control treatment showed the least harvest index of 44.7% which was lower than all the other fungicide treatments. The highest harvest index was obtained at carbendazim 100% which was significantly higher at 49.2% followed by carbendazim at 150% at 48.7% (Table 4).

3.5.4. Effect of Variety on Grain Yield

Grain yield was significantly ($P \leq 0.05$) different between the two varieties with Chania 1 giving a higher grain yield of 1.3 t/ha while Chania 2 gave a mean grain yield of 1.2 t/ha (Table 4). These variations could be due to the genetic differences between the two varieties.

3.5.5. Effect of Fungicide Treatments on Grain Yield

Fungicide rates had a significant ($P \leq 0.05$) effect on grain yield of chickpea. Highest grain yield of 1.4 t/ha was recorded when either thiram or carbendazim was seed dressed at 150% (i.e. 2.25 g/kg seed). This was followed by applying either carbendazim or thiram at 100% which had a mean grain yield of 1.3 t/ha. The lowest grain yield of 1.1 t/ha was observed when no fungicide treatment was used (Table 4). These results are corroborated De *et al*. [12] who noted that coating seeds with 0.2% carbendazim was more effective in reducing wilt and increasing yield. Kamdi *et al*. [11] reported low wilt incidence and maximum grain yields after applying carbendazim at 2 g/kg seed (i.e., 133.3% rate). Khalil *et al*. [18] reported that fungicide treatments increased grain yield in wheat as compared to untreated plots. Maitlo *et al*. [7] reported that fungicide treatment remarkably checked disease development and subsequently increased plant growth and yield as compared to untreated plants.

It can be inferred that treatment of chickpea with 150% and 100% thiram or carbendazim was very effective in controlling wilt incidence. The wilt pathogen releases phytotoxins [8] which leads to wilting, stunting, and chlorosis hence low dry matter. Application of fungicide protects the crop from the pathogen resulting in taller healthy plants, higher DM yields and better yield of chickpea. These findings are in agreement with research studies done by Halila and Strange [19] who found a positive correlation between seed yield, plant height and seed weight. Muhammad [9] found a direct correlation between inoculum density and wilt severity.

Table 4. Effect of variety and fungicide rate on yield, pods/plant, and seed weight and harvest index

Treatments Variety	Pods per plant	100 seed weight (g)	Harvest Index (%)	Grain Yield (T/ha)
ICCV 92944	114.19 a	19.7 a	45.68a	1.2 a
ICCV 97105	123.43 b	24.2 b	48.15b	1.3 b
LSD	2.5	3.9	0.8	0.02
C.V	0.6	0.5	0.5	0.5
Control	101.8 a	20.3 a	44.72a	1.15 a
$Thiram_{50\%}$	113.8 b	21.2 b	46.29b	1.21 b
$Thiram_{100\%}$	122.6 c	22.3 c	45.85b	1.31 c
$Thiram_{150\%}$	128.3 d	23.1d	46.68b	1.37 d
$Carbendazim_{50\%}$	113.8 b	21.3 b	46.87b	1.21 b
$Carbendazim_{100\%}$	123.0 c	22.3 c	49.29d	1.31 c
$Carbendazim_{150\%}$	128.2 d	23.1 d	48.70c	1.34 d
LSD	2.9	3.7	0.7	0.02
C.V	2.1	1.4	1.3	1.2

*Means followed by the same letter(s) in a column are not significantly different at P≤0.05 LSD.

3.6. Interaction Effects of Varieties with Fungicide Treatments on Grain Yield

Significant (P ≤ 0.05) interactions between varieties and fungicide treatments were observed (Table 5) on grain yield of chickpea. Chania 1interacted with either thiram or carbendazim applied at 150% yielding highest grain yield of 1.4 t/ha. Chania 2 interacted with thiram and carbendazim applied at 150% yielding grain yield of 1.3 t/ha (Table 5). The lowest grain yield was obtained with Chania 2 under control treatment with grain yield of 1.1 t/ha (Table 5). Application of fungicide as seed dress to MR Chania 1 resulted in a synergistic effect in terms of wilt management; with less pathogen establishment and this resulted in a healthier crop as compared to the lower fungicide rates and HS Chania 2. Thus, the healthy crop from moderately resistant Chania 1 interactions resulted in higher grain yield. Muhammad [9] reported a direct correlation between wilt severity and inoculum density. Inoculum density is adversely affected by fungicide application and use of resistant genotype. It is expected that to achieve a similar yield with HS Chania 2, it will require comparatively more fungicide treatment to arrest the pathogen.

Table 5. Interaction of variety with thiram or carbendazim on Grain yield of chickpea

Treatment	Grain Yield (T/ha)	
	92944	97105
Control	1.10a	1.19c
$Thiram_{50}$	1.14b	1.27d
$Thiram_{100}$	1.27d	1.34e
$Thiram_{150}$	1.32e	1.41f
$Carbendazim_{50}$	1.13b	1.28d
$Carbendazim_{100}$	1.27d	1.34e
$Carbendazim_{150}$	1.32e	1.41f
LSD	0.03	

3.7. Correlation Analyses of Yield Attributes

Grain yield was positively correlated (R=0.90) with dry matter at 120 DAS (final harvest). Plant height was positively correlated to dry matter and Grain yield. The number of pods per plant was positively correlated to grain yield with a high correlation coefficient R = 0.93 (Table 6). This means that a healthy (wilt free) chickpea crop would have tall plants of 32.6-35.5cm because of absence of the inhibiting phytotoxins released by the pathogen [8]. The healthy crop would also have more pods per plant in the range of 122.6 - 128.3; a higher rate of DM accumulation throughout the crop growth cycle, which would consequently translate into higher grain yield of over 1.3 t/ha. Grain yield was positively correlated to harvest index with a coefficient of 0.73 (Table 6). This observation was in agreement with Halila and Strange [19] who found a positive correlation between grain yield and plant height and hundred seed weight. Grain yield was negatively correlated to Fusarium wilt disease incidence, with correlation coefficient r of -0.94 and -0.95 at 45 DAS and 60 DAS, respectively (Table 6). Fusarium wilt incidence should be controlled early in order to increase grain yield because early wilting leads to more yield loss [17].

Plant height was positively correlated to dry matter. Dry matter was also positively correlated to number of pods per plant and harvest index (Table 6). Dry matter 120 DAS was negatively correlated to Fusarium wilt incidence both at 60 DAS and 45 DAS with respective r values of -0.83 and -0.95 which were significant (P ≤ 0.01). It was observed that as wilt incidence increased, DM yield was reduced due to low plant stand and low weight in infected plants (Table 6).

Number of pods per plant was positively correlated to harvest index and plant height with r values of 0.66 and 0.93 respectively both of which were significant(P≤0.01). Number of pods was however negatively correlated with Fusarium wilt incidence both at 60 DAS and 45 DAS with r values of -0.91 and -0.93, respectively (Table 6). Harvest Index (H.I) was positively correlated with plant height with an r value of 0.60, but negatively correlated with Fusarium wilt incidence both at 60 DAS and 45 DAS with r values of -0.70 and -0.60, respectively (Table 6). Studies by Halila and Strange [19] and Mallu *et al.* [16] showed a positive correlation between plant height and grain yield. Wilt incidence in chickpea leads to low dry matter which in turn leads to low grain yield hence low H.I values. Wilt incidence leads to low population and stunted crop which culminates into low yield [20]. Plant height was negatively correlated with Fusarium wilt incidence at 60 DAS and 45 DAS giving r values of -0.87 and -0.95, respectively (Table 6). These results were in agreement with Haware and Nene (1980) [17] who reported stunting in infected plants. Muhammad [9] reported a direct correlation between wilt severity and pathogen inoculum density. This means that as fungicide rate was increased, plant height was improved due to low infection by the pathogen. Maitlo *et al*. [7] also found that increasing fungicide rates improved shoot height by reducing wilt incidence. Fusarium wilt incidence at 60 DAS was positively correlated with Fusarium wilt incidence at 45 DAS with an r value of 0.92 which was significant ($P \leq 0.01$) (Table 6). This means that wilt incidence observed at 45th DAS was likely to incite more wilt incidence at 60th DAS and therefore alternative management options should be adopted.

Table 6. Correlation between yield parameters and Fusarium wilt incidence

	DM 120	Grain yield	Pods/plant	Harvest index	Plant height	DI 60 DAS
Dry matter 120						
Grain yield	0.90**					
Pods/plant	0.87**	0.93**				
Harvest Index	0.50**	0.73**	0.66**			
Plant Height	0.90**	0.92**	0.93**	0.60**		
DI 60 DAS	-0.83**	-0.94**	-0.91**	-0.70**	-0.87**	
DI 45 DAS	-0.95**	-0.96**	-0.94**	-0.61**	-0.95**	0.92**

** Significant at $P \leq 0.01$; * significant at $P \leq 0.05$. $r_{(24,0.05)}$ =0.388, $r_{(24, 0.01)}$ =0.496. DI – Disease incidence

4. Conclusion

Highest grain yields of 1.4 and 1.32 t/ha were recorded when carbendazim and thiram were seed dressed at 150% (2.25 g/kg seed), respectively. Significant interactions between variety and fungicide treatments were observed on yield parameters. Growing moderately resistant Chania 1 chickpea at 100% recommended rate of 1.5g/kg seed gave equal yields as growing susceptible Chania 2 chickpea at 2.25 g/kg seed dressing rates (150%). Disease incidence at 45 days after sowing recorded high negative correlation coefficients of -0.96, -0.94 and -0.93 for grain yield, plant height and pods/plant. Therefore, observing disease severity at 45 DAS can be a good indicator for prediction of yield and yield attributes. Further studies on these are recommended.

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