Phytology

Yield potential and root-knot nematode (*Meloidogyne incognita*) resistance of six tomato (*Solanum lycopersicum* L.) genotypes

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Abstract

Six tomato genotypes were investigated for their yield and root-knot nematodes resistance potential. The screen house experiment was conducted at CSIR-Crops Research Institute in Kumasi, Ghana. Yield per ton was computed from fruit yield per plant and the reproductive potential of nematodes on the genotypes was determined using Oostenbrink's reproduction factor (RF). Reproduction factor was determined as the final egg density (Pf) over the initial egg density (Pi) and mathematically represented as Rf = (Pf/Pi). Besides, plant height, average fruit weight and root-gall index were assessed. Significant differences ($p \leq 0.001$) were observed in average fruit weight and yield per plant amongst the six tomato genotypes. The treatment BC 1.1 recorded the greatest fruit weight (24.00) g while P_2 recorded the lowest (11.13) g. Thus, BC $_{1.1}$ out-weighed P_2 by approximately 53.6%. Similarly, $BC_{1.1}$ (8.70 t/ha) out-yielded P_2 (2.84 t/ha) by approximately 67.4%. Plant height however, did not record differences amongst treatments. Treatments reacted differently to root knot nematodes parasitism resulting in different levels of root gall formation. The treatment P_2 recorded the least index of 0.97 while P_1 recorded the highest index of 8.10. Reproduction factor followed the same pattern as P_2 recorded the lowest (0.06) and P_1 the highest (2.93). The treatments P_2 and P_1 were considered resistant and susceptible respectively.

Keywords: ghana, therapeutic values, parental line, reproduction factor, photosynthate

1. Introduction

Tomato (*Solanum lycopersicum* L.) is one of the major vegetables cultivated in Ghana that contributes enormously to the socio-economic development of the country. The tomato industry engages over 90,000 farmers, 5,000 traders and about 3,000 other individuals who play different roles in the tomato value chain (Robinson & Kolavalli, 2010) [17].

According to Biswas *et al*. (2020) [2], tomato is a rich source of lycopene antioxidant that moderates the threat of prostate cancer (Kaushik *et al*., 2011) [13]. The vegetable crop has therapeutic values and is used for blood decontamination and cure of gastrointestinal diseases. It has an exceptional source of diverse vitamins like A, C and minerals like calcium, potassium, phosphorus, magnesium and iron, carotenoids, flavonoids and phenolics for human diet (Gerszberg *et al*., 2015; Horneburg & Myers, 2012; USDA, 2009) [7, 9, 23].

In Ghana, tomato is cultivated throughout the year under rain-fed conditions that normally stretches from June to November in the southern part of the country. There is the dry-season system between October and April mainly in the north, especially in the Upper East region (Asante *et al.*, 2013) [1]. The major tomato producing communities include; Tono, Vea and Navrongo in the Upper East, Akumadan, Agogo and Ejura in the Ashanti, Wenchi in the Brong Ahafo, Sege and Dodowa in the Greater Accra regions, The common tomato varieties cultivated are; Roma, Pectomech, Burkina, Royal and Power (Khor, 2006) [14].

Unfortunately, yield of tomato per hectare basis is very low with an average yield of less than 10 tons per hectare (Robinson & Kolavalli, 2010) [17]. The low productivity could be attributed to several biotic and abiotic factors such as the sensitivity and vulnerability of the plant to various diseases including fungal, viral, bacterial and nematode infections as well as inclement weather conditions and high post-harvest losses (Reddy, 2018) [18]. The most commonly occurring insect pests include; whiteflies, thrips, aphids and tomato fruit worm. These insect pests are considered important based on their economic impacts on tomato production worldwide (Lammer & MacLeod, 2007; Enomoto, 2008; Gianessi, 2009) [15, 5, 6]. Tomato production in Ghana is however, seriously threatened by root knot nematode (*Meloidogyne* spp.), which are responsible for huge economic yield losses. They are considered to be the most destructive and difficult pest to control in tropical and subtropical countries (Subbotin *et al.*, 2021) [20]. Four (4) decades ago, Hemeng (1981) [10] reported in Northern Ghana that root-knot nematodes infestation alone resulted in significant yield losses ranging from 73 to 100% in one season. This paper investigates the yield performance and root knot nematodes resistance of six genotypes of tomato.

2. Materials and Methods

The study was conducted at the Horticulture Division, Council for Scientific and Industrial Research (CSIR)-Crops Research Institute (CRI) Kwadaso, Kumasi. The study site is located at Lat 6˚ 40' 40" N and Long 1˚ 40' 0.6" W. The site falls within the semi-deciduous rain forest zone with a bimodal rainfall pattern featuring the major (April-July) and minor (September-December) seasons. An average annual rainfall of 1500 mm, maximum and minimum mean temperatures (32.7˚C and 22.7˚C) respectively characterized the study site during the period of experimentation in the year 2020.

2.1. Experimental materials

Previous studies on evaluation of tomato genotypes for resistance to root knot nematode (Unpublished masters' thesis; Gyau, 2019) [8] led to the development of six $F_{1's}$ at the CSIR-Crops Research Institute. These F_1's were validated using appropriate molecular markers for the presence of the Mi gene. Parental lines used for the development of the F_1's were selected based on uniformity in fruit colour and fruit shape. Among the six F_1's, only one of them (P005 ♀ × VFNT ♂) was selected and used for the current study. Availability of sufficient seeds informed the selection of the parental line used in the current study. The accession P_1 coded P005 and P_2 coded VFNT were obtained from Ghana and USA respectively (Table 1). The six populations developed for the study were; P_1, P_2, F_1, F_2, $BC_{1.1}$ and $BC_{1.2.}$

Table 1: Tomato accessions used for the study

Accession	Code	Source
P_1	P005	Ghana
P_2	VFNT	VFNT

2.2. Preparation of nematode culture

Nematode eggs were extracted from *Meloidogyne incognita* infested tomato roots collected from a screen house at Crops Research Institute using Hussey and Barker (1973) [11]. The infested roots were washed under running tap water and cut into pieces with a sharp knife on a chopping board. The cut roots were then macerated with a kitchen blender. About 100 ml of de-ionised water was added to the macerated roots in a jar. The jar was covered tightly and shaken vigorously. The suspension was poured into a 105µm sieve mounted over a 45µm sieve. Egg masses flowed through the 105µm sieve and collected by a 45µm sieve below. The egg masses were then scooped into the extraction tray with a plastic spoon. The process was repeated several times in other to obtain sufficient egg masses. The eggs were later incubated using the extraction tray method after Coyne *et al.* (2007) [4]. The process involved spreading of the egg masses on a 2- ply tissue paper nested in a small plastic basket. The plastic basket with its content was placed in shallow plastic tray set on a level bench. About 100 ml of de-ionized water was gently added by the side of each tray and the set-up left for 48h. The water level was topped up in case it reduced through evaporation. After 48h, second stage nematode suspension in the plastic tray/ was shaken gently and poured into a beaker for counting. The collected juveniles were used for inoculating two-week old tomato seedlings established in pots (Fig, 1).

Fig 1: Tomato seedlings in the screen house awaiting inoculation

2.2.1. Inoculation of treatments

The inoculum consisted of a suspension of second stage juveniles and each of the six treatments was inoculated with a suspension of one thousand second stage juveniles. The treatments (P_1, P_2, F_1, F_2, $BC_{1.1}$ and $BC_{1.2}$) were replicated three times. The inoculum suspension was dispensed with a pipette in a circular form in a shallow hole 0.5 cm away from the base of each tomato seedling. The treatments were watered immediately after inoculation to preserve the inoculum and subsequently as and when watering was needed to prevent damping off.

2.3. Data collection

Data collected included; Plant height, average fruit weight, fruit yield per plant, root gall index and reproduction factor. Plant height was measured with a tape measure. Average fruit weight and fruit yield per plant were assessed by weighing on an electric scale, KERN® (KERN & SOHN, Germany).

Root gall index (RGI) was scored on a scale of 0-10 according to (Bridge & Page, 1980) [3] where 0= No galls on roots, 1= Few small galls difficult to find, 2= Small galls only but clearly visible. Main roots clean, 3= Some larger galls visible. Main roots clean, 4= Larger galls predominate but main roots clean, 5= 50% of roots infested. Galling on parts of main roots. Reduced root system. 6= Galling on main roots, 7= Majority of main roots galled, 8= All main roots galled. Few clean roots visible, 9= All roots severely galled. Plant usually dying and 10= All roots severely galled. No root system. Plant usually dead.

The reproductive potential of nematodes was determined using Oostenbrink's reproduction factor (Rf) (Windham & Williams, 1987) [24]. Reproduction factor (Rf) was assessed as final egg density (Pf) over initial egg density (Pi). Thus, Rf = (Pf/Pi).

2.4. Data analysis

Data recorded were subjected to Analysis of Variance (ANOVA) using the GenStat 12th edition statistical package. Both discrete and continuous data were not transformed before analysis. The Least Significance Difference (LSD) test at 5% was used to separate treatment means.

3. Results and Discussion

The mean performance for three of the tested traits in six genotypes of tomato are presented in Table 2. The investigation revealed that two of the three traits (average fruit weight and fruit yield per plant) recorded significant ($p \leq 0.001$) differences. Plant height however did not record differences ($p>0.05$) amongst the genotypes. Plant height influences yield positively since more foliage production support higher photosynthate production (Tyagi *et al.*, 2015) [22]. Plant height ranged from 46.90 cm in P_1 to 50.00 in P_2. Lack of differences in plant height could be attributed to the fact that the six genotypes were developed from a single parental line and therefore are isogenic lines.

However, the genotypes exhibited significant differences in average fruit weight. The greatest fruit weight (24.00) g was recorded in $BC_{1.1}$ while P_2 recorded the lowest (11.13) g. Thus, $BC_{1.1}$ out-weighed P_2 by approximately 53.6%. Differences might be due to genetic factor.

Yields though abysmally low, recorded significant differences ($p \leq 0.001$). The $BC_{1.1}$ treatment had the highest yield (0.44) g

per plant while the lowest (0.14) g was recorded in P_2. Thus, $BC_{1.1}$ out-yielded P_2 by approximately 68.2%. Generally, yields in pot experiments are significantly lower compared with field experiments. In his research "The perils of pot experiments" Passioura (2006)[16], observed that hypoxia condition that normally attends pot experiments could result in lower yields (Table 2).

Fig 2: A susceptible tomato genotype showing severe gall formation

Fig 3: A resistant tomato genotype with virtually no galls

According to Tarner and Adrienne (2020) [21]. root-knot nematode parasitism results in susceptible genotypes developing excessive root galls (Fig. 2) while resistant genotypes develop insignificant or no galls at all (Fig. 3). Treatments reacted differently to root knot nematodes parasitism resulting in different levels of root gall formation. Root gall index ranged from 0.97 in P_2 to 8.10 in P_1. From the analysis, P_2 (0.97) was considered resistant, F_1 and $BC_{1.2}$ which recorded (1.50 and 1.57) respectively were regarded as moderately resistant, F_2 and $BC_{1.1}$ (3.38 and 3.57) respectively were tolerant and P_1 (8.10) susceptible (Fig. 4).

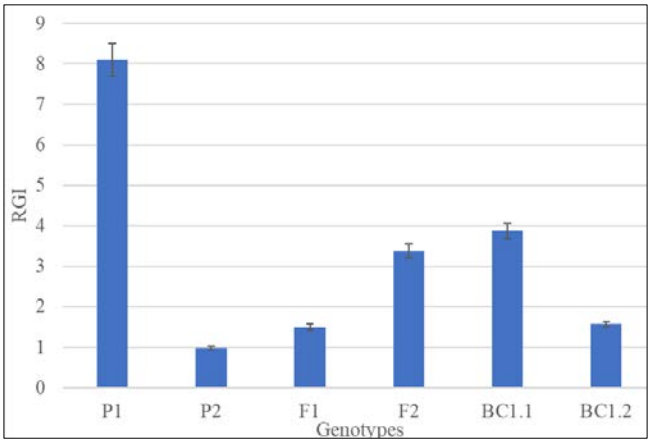

Fig 4: Root-galling level of the six tomato genotypes

The reproduction factor among tomato genotypes varied significantly from 0.06 on (P_2) to 2.93 on (P_1). Similarly, the other treatments; F_1, F_2, $BC_{1.1}$, and $BC_{1.2}$ reacted differently to nematode reproduction. F_1, F_2, and $BC_{1.2}$ recorded (0.65, 0.38 and 0.38) respectively while $BC_{1.1}$ recorded (1.24) (Fig.5). Reproduction factor values were inversely related to P_1 for genotypes and were lowest on P_2 (0.06) with P_1 (2.93) maintaining highest Rf values. By the conditions of this study, P_2 was considered resistant, F_1, F_2 and $BC_{1.2}$ were moderately resistant, $BC_{1.1}$ was tolerant while P_1 was susceptible. Kamran *et al.*, (2012) [12] observed that reproduction and galling of nematodes on plant root were favoured on tolerant and susceptible cultivars but inhibited on resistant ones. Because resistance to nematodes is usually developed by selection of plants with reduced rates of nematode reproduction and galling, nematode population densities are typically lower in cultivars with resistance genes than a susceptible cultivar (Sorribas, Ornat, Verdejo-Lucas, Galeano & Valero, 2005) [19].

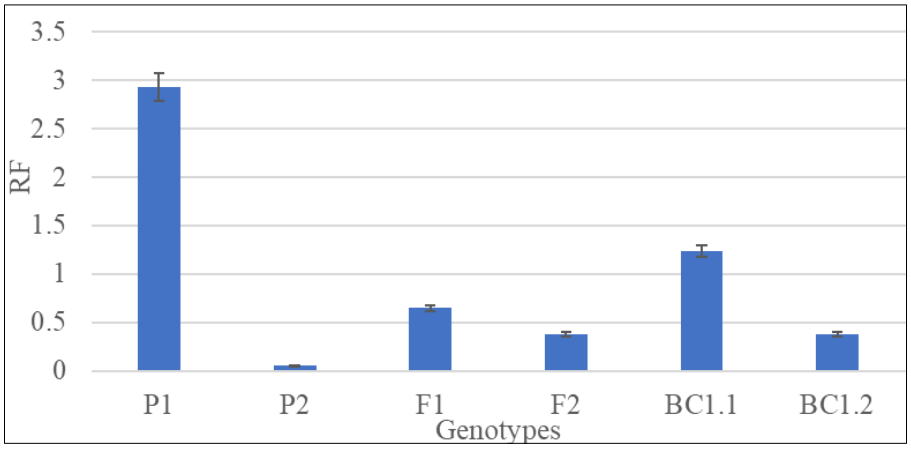

Fig 5: Root-knot nematodes reproduction on the six tomato genotypes

Table 2: Agronomic traits of the six tomato genotypes

Genotype	Plant height (cm)	Average fruit weight (g)	Fruit yield per Plant (kg)	Yield (t/ha)
P_1	46.90 a	17.87 abc	0.36 b	7.22 bc
P_2	50.00 a	11.13 a	0.14 a	2.84 a
F_1	49.53 a	14.07 ab	0.29 ab	5.82 abc
F_2	49.67 a	18.94 abc	0.38 b	7.61 bc
$BC_{1.1}$	48.20 a	24.00 c	0.44 b	8.70 c
$BC_{1.2}$	47.90 a	22.00 bc	0.34 ab	5.27 bc
Mean	48.85	19.17	0.34	6.25
Sed	1.27	1.32	0.03	0.90
CV (%)	4.30ns	10.20**	8.90**	19.30**

** = Significant at p = 0.01 probability level, ns = not significant,
# 0=No galls on roots, 10=All roots severely galled, plant usually dead
RF < 1= no reproduction and RF > 1= reproduction occurred

4. Final Considerations

Yield performance and root knot nematode resistance of the six tomato genotypes have shown that F_2 and $BC_{1.1}$ out – yielded all the other genotypes while treatments reacted differently to root knot nematodes parasitism resulting in different levels of resistance. The two genotypes (F_2 and BC_{11}) would be studied further for their stability in yield and quality traits under different experimental environments. The benefits of resistant tomato genotypes are numerous but those that come readily to mind include; high productivity, reduced economic losses and enhanced livelihoods for the farmer.

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