American Journal of Agriculture and Forestry
2017; 5(2): 16-19
http://www.sciencepublishinggroup.com/j/ajaf
doi:10.11648/j.ajaf.20170502.11
ISSN: 2330-8583 (Print); ISSN: 2330-8591 (Online)

SciencePG Science Publishing Group

Determination of Optimum Nativo SC 300 (Trifloxystrobin 100g/l + Tebuconazole 200g/l) Spray Frequency for Control of Rust (Puccinia allii Rudolphi) on Garlic in Bale Highlands, South Eastern Ethiopia

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To cite this article:
Yonas Worku Mulat. Determination of Optimum Nativo SC 300 (Trifloxystrobin 100g/l + Tebuconazole 200g/l) Spray Frequency for Control of Rust (Puccinia allii Rudolphi) on Garlic in Bale Highlands, South Eastern Ethiopia. *American Journal of Agriculture and Forestry.* Vol. 5, No. 2, 2017, pp. 16-19. doi: 10.11648/j.ajaf.20170502.11

Received: April 23, 2016; **Accepted**: May 3, 2016; **Published**: March 15, 2017

Abstract: Garlic (Allium sativum L.) is one of the major allium crops grown in the highlands of Bale, south eastern Ethiopia. Rust, which is caused by Puccinia allii Rudolphi is the most important disease of this crop in these areas. There are different fungicides recommended for the control of garlic rust on *Allium* crops in different parts of the world. Nativo SC 300 (Trifloxystrobin 100g/l + Tebuconazole 200g/l) is one of the recommended chemicals for the control of this disease. To determine the optimum Nativo SC 300 spray frequency for the control of the disease a study was conducted at research station of Sinana Agricultural Research Center, south eastern Ethiopia. The fungicide was sprayed on garlic plots in three different frequencies. The frequencies were five times (every 7-days), three times (every 14-days) and two times (every 21-days) starting from the onset of the disease. The experiment was laid down in Randomized Complete Block Design with three replications. The lowest average rust severity level (1%) was recorded from plots which were treated with the fungicide five times at weekly interval whereas the maximum average severity level (83.3%) was recorded from the unsprayed plots. All fungicide treated plots gave significantly ($p \leq 0.05$) higher total bulb yield than the untreated check plots. Among fungicide treated plots, the maximum total bulb yield (13.92 t/ha) was obtained from plots which were protected from the disease by spraying the fungicide three times at 14-days interval. Partial budget analysis revealed that application of Nativo SC 300 three times at 14-days interval gave the highest net benefit. Therefore, application of Nativo SC 300 (Trifloxystrobin 100g/l + Tebuconazole 200g/l) three times at 14-days interval starting from the onset of the disease results in not only high total bulb yield but also high net benefit on the chemical application.

Keywords: Allium Sativum L., Garlic, Nativo SC 300, Puccinia Allii, Rust

1. Introduction

Garlic (*Allium sativum* L.) is one of the most ancient cultivated herbs in the world. It is a member of Amaryllis family (Amaryllidaceae) [7]. Its close relatives include the onion, shallot, and leek [2]. Next to onion, garlic is the second most widely cultivated *Allium* species in Ethiopia [3]. In the highlands of Bale, farmers produce garlic under both irrigation and rain fed condition during both '*Bona*' (August to December) and '*Gena*' (March to July) cropping seasons for commercial purpose [13].

Production of this crop is constrained by several biotic and abiotic factors. Insects and fungi are the major pests of the crop in different parts of the world [4]. Among the fungal diseases, garlic rust caused by *Puccinia allii* Rudolphi is the most important disease of the crop in almost all garlic producing regions of Ethiopia [10, 13].

Puccinia allii infects garlic at bulb formation stage [11]. The earliest symptom of this disease is small, circular to elongate white flecks that occur on both sides of the leaves. As the disease progresses, these small spots expand, and the leaf tissue covering the lesions ruptures and masses of orange, powdery spores (uredospores) then become visible as pustules. Severely infected leaves are almost entirely covered with pustules, resulting in extensive yellowing, wilting and premature drying of leaves [5].

Garlic rust is the most important disease of the crop in the highlands of Bale and causing a total bulb yield loss as high as 58.75% [13]. The fungus does not attack the garlic bulb directly, but its damage on the leaves has indirect effect of reducing the size and quality of the bulbs at harvest [5, 9].

Hence, application of control measures is necessary to minimize these losses. To control this disease, quite a few options are available. Use of resistant varieties is cheaper and environment-friendly but such varieties are not available. No commercial biological control is available either. Because of wind-dispersal and easy spread of the disease, cultural practices can hardly work. This leaves us with only one available option, the chemical control [9].

There are different fungicides recommended for the control of garlic rust on different *Allium* crops in different countries [5, 12, 13]. Nativo SC 300 (Trifloxystrobin 100g/l + Tebuconazole 200g/l) is one of the recommended chemicals for the control of the disease [6]. One of the active ingredients of this fungicide, tebuconazole, is found effective in controlling garlic rust in Ethiopia [13]. Spraying a fungicide for the control of a given disease at different frequency has different effect on the development of the disease. Application of tebuconazole on a garlic field eight times at weekly interval resulted complete control of garlic rust [13]. However, such frequency may not be economical and application frequency should be based on economic analysis with consideration of the costs of fungicide application and return from yield recovery [13]. Therefore, this experiment was initiated with the objective of determining optimum Nativo SC 300 (Trifloxystrobin 100g/l + Tebuconazole 200g/l) spray frequency for the control of garlic rust in Bale highlands.

2. Materials and Methods

Uniform sized cloves of a local garlic variety were planted at spacing of 0.3m and 0.1m between rows and plants, respectively in plots size of 1.8m x 2.5m. The plots were fertilized with DAP and UREA at recommended rates 200 and 150 kg-ha^{-1}, respectively. During the onset of the target disease, garlic rust, Nativo SC 300 (Trifloxystrobin 100g/l + Tebuconazole 200g/l) was sprayed on the experimental plots at a rate of 1 l-ha^{-1}. Spray was continued at three different intervals; every 7-, 14- and 21-days. Spray frequencies for every 7-, 14- and 21-days interval were five, three and two, respectively. Unsprayed plots were also included to allow maximum rust severity for comparison. During fungicide application, plastic sheet was used to separate the plot being sprayed from the neighboring plots to prevent inter-plot interference due to spray drift. The plots were laid down in Randomized Complete Block Design with three replications. The experiment was conducted at research station of Sinana Agricultural Research Center, south eastern Ethiopia, during '*Bona'* (August to December) cropping season of 2015.

Garlic rust severity was assessed from 24 plants which were randomly pre-tagged with linen tie in the middle four rows of each plot (six plants per row). Disease severity was estimated in percentage of the leaf surface covered with lesions. It was assessed from all leaves of each plant and the average was taken (recorded) for the respective plant. Average severity level of the 24 plants per plot was used for statistical analysis.

Data of bulb weight, total bulb yield and days to maturity were collected as follows.

1. Bulb weight (g): mean weight of 15 bulbs from each plot after curing.
2. Total bulb yield (t/ha): yield estimated from the middle four rows (100 plants) of each plot and converted to tons per hectare.
3. Days to maturity: number of days from planting to 95% of the plants are matured.

Data on rust severity, bulb weight, total bulb yield and days to maturity were subjected to analysis of variance by using SAS 9.1.3. computer software. Least significant difference (LSD) values were used to separate differences among treatment means.

Partial budget analysis was employed for Nativo SC 300 (Trifloxystrobin 100g/l + Tebuconazole 200g/l) application and it was carried out for total bulb yield data. To estimate economic parameters, total bulb yield was valued at an average open market price of 25 Ethiopian birr (ETB)/kg. To estimate the total costs, mean current prices of Nativo SC 300 (750 ETB/l), water (0.05 ETB/l) and soap (10 ETB each piece). Two workers for Nativo SC 300 calibration and application were considered for a hectare per day. The wage rate per worker was 100 ETB per day. Cost of land preparation, field management, harvest and planting material were not included in the calculation. The partial budget analysis was based on the formula developed by CIMMYT [1] and given as follows:

Gross Average Yield (GAY) (q/ha): is an average total bulb yield of each treatment

Adjusted Yield (AJY) (q/ha): is the average total bulb yield adjusted down ward by a 10% to reflect the difference between the experimental yield and yield of farmers.

AJY = GAY - (GAY * 0.1)

Gross Field Benefit (GFB): was computed by multiplying field/farm gate price that farmers receive for the crop when they sale it as adjusted yield.

GFB = AJY * field/farm gate price of the crop

Total Cost (TC): mean current prices of Nativo SC 300 (750 ETB/l), water (0.05 ETB/l), wage for fungicide application (100 ETB/person) and soap for cleaning (10 ETB/piece) were considered per hectare.

Net Benefit (NB): was calculated by subtracting the total costs from the gross field benefit for each treatment.

NB = GFB – TC

Marginal Cost (MC) = change in costs between treatments

Marginal Benefit (MB) = change in benefits between treatments

Marginal Rate of Return (MRR (%)) = (MB/MC) * 100

3. Results and Discussions

Rust severity level on all fungicide treated plots was significantly ($p \leq 0.05$) lower than the unsprayed plots. This shows that, the fungicide, Nativo SC 300 (Trifloxystrobin 100g/l + Tebuconazole 200g/l), was effective in controlling the disease and this finding agrees with Pira *et al.,* [6]. Among fungicide sprayed plots, the highest severity level (11.7%) was recorded from plots which were protected from the disease by spraying the fungicide twice between 21-days starting from the onset of the disease while the lowest severity level (1%) was recorded from five times sprayed plots at weekly interval. However, there was no significant ($p > 0.05$) garlic rust severity level difference among plots treated with the fungicide at different frequencies. Spraying the fungicide thrice between 14-days was as effective as spraying it five times in every 7-days starting from the onset of the disease (Table 1).

Average weight of bulbs harvested from fungicide sprayed plots was significantly ($p \leq 0.05$) higher than the weight of bulbs which were harvested from the unsprayed plots. Although there was no significant ($p > 0.05$) weight difference among bulbs harvested from fungicide sprayed plots, the highest average weight (42.8g) was recorded from bulbs which were protected from the disease by spraying the fungicide three times at 14-days interval whereas the lowest average weight (39.3g) was recorded from bulbs which were sprayed with the fungicide twice between 21-days starting from the onset of the disease (Table 1).

All fungicide treated plots gave significantly ($p \leq 0.05$) higher total bulb yield than the unsprayed plots. However, there was no significant difference among total bulb yield harvested from fungicide sprayed plots. And the highest total bulb yield (13.92 t/ha) was obtained from plots in which Nativo SC 300 was sprayed thrice in every 14-days whereas the lowest (12.83 t/ha) was harvested from plots treated with the fungicide twice at 21-days interval. Plots sprayed with the fungicide three times at 14-days interval had about 106% total bulb yield advantage over the unsprayed plots. Spraying the fungicide twice between 21-days had 99% total bulb yield advantage over the unprotected plots (Table 1). This result proves that rust causes considerable total bulb yield loss on garlic if control measure is not applied [5, 13].

There was significant ($p \leq 0.05$) days to maturity (DTM) difference between garlic plots sprayed with the fungicide at different frequencies and the unsprayed check plots. The DTM of all fungicide sprayed plots was statistically longer than the DTM of the unsprayed plots. However, the DTM of all plots under different Nativo SC 300 spray frequencies were not statistically different (Table1). The reason why the days to maturity of all fungicide sprayed plots were longer as compared to the unsprayed ones is, garlic plants in the unsprayed plots were severely infected by the disease and garlic leaves that are heavily infected by rust dry prematurely [5, 8, 13].

The result of partial budget analysis of Nativo SC 300 application on garlic field proved an increase in net benefit due to fungicide application which resulted higher total bulb yield. Spraying Nativo SC 300 twice at 21-days interval starting from the onset of the disease insured a gain of 134,830 Ethiopian Birr (ETB)/ha additional net benefit. When the spray frequency increases from two (every 21-days) to three times (every 14-days) the net benefit increases from 286,705 ETB/ha to 310,245 ETB/ha. Consequently, the additional net benefit increases to 23,540 ETB/ha. When the spray frequency increased from three to five times, the net benefit decreased from 310,245 ETB/ha to 297,700 ETB/ha (Table 2).

Table 1. *Mean terminal rust severity, bulb weight, total bulb yield, relative yield advantage over the unsprayed control and days to maturity of garlic under different Nativo SC 300 (Trifloxystrobin 100g/l + Tebuconazole 200g/l) spray frequencies in 2015 at Sinana Agricultural Research Center, Ethiopia.*

Spray intervals	Terminal rust severity (%)	Bulb weight (g)	Total bulb yield (t/ha)	Relative yield advantage over the unsprayed check (%)	DTM
Between 14 days	3.7	42.8	13.92	106.2	161
Between7 days	1.0	41.6	13.45	99.3	159.3
Between 21days	11.7	39.3	12.83	90.1	160.7
Unsprayed control	83.3	22.7	6.75		148.3
CV (%)	15.4	12.7	12.75		2.4
LSD(0.05)	10.9	13.1	4.23		10.5

Where DTM–days to maturity, g–gram, t/ha–tons per hectare

Table 2. *Partial budget analysis of Nativo SC 300 (Trifloxystrobin 100g/l + Tebuconazole 200g/l) application on garlic for control of rust (Pucciniaallii) in the highlands of Bale, south eastern Ethiopia.*

	Spray frequencies			
	Unsprayed	Two times	Three times	Five times
Gross average yield (q/ha)	67.5	128.3	139.2	134.5
Adjusted yield (q/ha)	60.75	115.47	125.28	121.05
Gross field benefit (ETB)	151,875	288,675	313,200	302,625
Total cost that vary (ETB)	0	1970	2955	4925
Net benefit (ETB)	151,875	286,705	310,245	297,700D[a]
Marginal cost		1,970	985	
Marginal benefit		134,830	23,540	
Marginal rate of return (MRR)		6,844	2,390	

[a]-Dominated

Where q/ha-quintals per hectare, ETB-Ethiopian Birr

4. Summary and Conclusions

Garlic rust *(Puccinia allii* Rudolphi*)* severity level on garlic plots sprayed with the three different Nativo SC 300 (Trifloxystrobin 100g/l + Tebuconazole 200g/l) spray frequencies (five times in every 7-days, three times in every 14-days and two times in every 21-days) was lower as compared to the unsprayed plots. Among fungicide sprayed plots, the lowest level of severity was recorded from plots which were sprayed with the fungicide five times between 7-days interval. Hence, spraying the fungicide five times between 7-days interval starting from the onset of the disease is the most effective frequency in controlling the disease. However, such frequency did not result in highest total bulb yield.

Regarding total bulb yield all spray frequencies gave higher total bulb yield than the unsprayed check plots. Among fungicide treated plots, the highest total bulb yield was harvested from plots on which Nativo SC 300 was sprayed three times between 14-days interval. Hence, application of the fungicide three times between 14-days interval starting from the onset of the disease results higher total bulb yield than applying it either five times between 7-days or two times between 21-days intervals.

The partial budget analysis proved that application of Nativo SC 300 three times between 14-days provided the highest net benefit. Hence, controlling rust in a garlic field by spraying SC 300 three times between 14-days interval results higher net benefit than controlling it between 7- or 21-days intervals starting from the onset of the disease.

Hence, the results of this study proved that, controlling rust (*Puccinia allii* Rudolphi) from a garlic field by spraying Nativo SC 300 (Trifloxystrobin 100g/l + Tebuconazole 200g/l) three times at 14-days interval starting from the onset of the disease results in not only high total bulb yield per hectare but also high net benefit on the chemical application.

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