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Research Article

PLANT DISEASES FOR MAJOR CROPS IN EGYPT UNDER FUTURE CLIMATE CONDITIONS

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ABSTRACT

The impacts of climate change can be positive, negative or neutral, since these changes can decrease, increase or have no impact on diseases, depending on each region or period. The aim of this study is to evaluate the impact of climate change on plant diseases which are most infection for the five strategic crops (Maize, Wheat, Faba Bean, Tomato and Potato) in Egypt. The evaluation has been done on the basis of assessing the favorable weather conditions for disease infection according to future climate data. The climate change data has been obtained from downscaling on global climate model ECHAM6 of scenario RCP 4.5 by a horizontal resolution 50 km during the period from 2010 up to 2090, and the results indicated that, the highest availability of the favorable conditions for infection will be in Lower Egypt followed by Middle and Upper Egypt Governorates, and the infection rate tend to increase in the future except in the diseases which depend on wet condition where this condition will decrease in the future at Lower and Middle Egypt Governorates.

INTRODUCTION

Environmental conditions have a major influence on the survival, propagation and dispersal of plant pathogens. The effects of the climate are perhaps most obvious for fungal pathogens, which require suitable temperatures and minimum amounts of moisture to survive and reproduce and to initiate the infection process in plants (Fahim *et al.,* 2013). Most pathogens complete part of its life cycle on this host plants and the remaining part in the soil or on plant residues in the soil. Thus, temperature and moisture conditions in both air and soil are important for pathogen survival and development (Chancellor and Kubiriba, 2006). The analysis of the potential impacts of climate change on plant diseases is essential for the adoption of adaptation measures, as well as for the development of resistant cultivars, new control methods or adapted techniques, in order to avoid more serious losses (Chakraborty and Pangga, 2004). Diseases are responsible for losses of at least 10% of global food production, representing a threat to food security (Strange and Scott, 2005). Plant health is predicted to generally suffer under climate change through a variety of mechanisms, from accelerated pathogen evolution and shorter incubation periods to enhanced abiotic stress due to mismatches between ecosystems and their climate and the more frequent occurrence of extreme weather events (Newton *et al.,* 2011 and Sutherst *et al.,* 2011). The first and second Egyptian communications reports, mentioned that Egypt is one of the most vulnerable countries to the potential impacts and risks of climate change (Fahim *et al.,* 2013). More studies were made to assess the potential impacts of climate change on crop productivity and reported that climate change impacts will negatively affect the crops productivity due to plant exposure to pests and diseases. The recent scientific observations concluded that the severe epidemics of tomato late blight (*Phytophthora infestans*) emerged in the last few years. In practice, an epidemic onset is expected to lead to 2-4 additional sprays to be applied at the coming decades of the 2025-2100. (Fahim *et al.,* 2007 and 2010), represent that a challenge for potato late-blight researches in the future to find a balance between reduction use of pesticides and the pressure to increase pesticide utilize due to climate change. The Severity of some pests and disease affecting the strategic crops have increased in the last few decades, this increase in severity is mainly attributed to both climatic and socio-economic reasons (Abolmaaty *et al.,* 2010 and Yones *et al.,* 2011). The objective of this study is to evaluate the impact of climate change on plant diseases which are most effective on the strategic crops (Maize, Wheat, Faba Bean, Tomato and Potato) in Egypt.

MATERIAL AND METHODS

Study areas

The study was carried out on the Governorates which have largest cultivated area from the determined crops distributed in different geographic regions (Lower, Middle, and Upper Egypt)

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based on the Bulletin of the Agricultural Statistics (BAS) 2013 and 2014 records according to table (1).

Table 1 Governorates which have largest cultivated area from the determined crops in (Lower, Middle, and Upper Egypt) regions based on BAS 2013 and 2014 records

Crop	Studied/Selected Governorates
Maize	Sharqia – Monufia - Beni Suef - Minya- Asyut - Sohag
Wheat	Sharqia – Behera – Minya – Faiyum – Asyut - Sohag
Faba bean	Behera - Kafr El sheikh – Giza – Faiyum – Asyut - Aswan
Tomato	Sharqia – Ismailia – Faiyum – Giza – Qena - Asyut
Potato	Dakahlia – Behera – Beni Suef – Giza - Sohag - Aswan

Crop diseases evaluation

Evaluating the plant diseases in future will be done on the basis of studying the potential of achieving the favorable weather conditions under future climate data for the crop diseases which are shown in table (2). Also the severity of occurrence these conditions have been assessed and classified in five classes (*Non severe, Low, Moderate, High, and Extreme*) according to the number of its occurrence/achieving in each crop season as shown in table (3).

Table 2 Favorable weather conditions for the studied/determined crop disease

Crop	Disease		Weather conditions		Reference
Maize	**Late wilt of maize** *(Harpophora Maydis)*		21 - 27°C	Moisture conditions	Singh and Siradhana, 1987a; Khokhar *et al.*, 2014
wheat	**Leaf rust of wheat** *(Puccinia triticina)*		59 - 71° F	water on the leaf surface from intermittent rains or heavy dews	Marsalis *et al.*, 2006
Faba bean	**Chocolate leaf spot of Faba bean**		15-22 °C	High Relative humidity (>80%)	Harrison, 1988; Stoddard *et al.*, 2010
Tomato	**Late blight of Tomato** *(Phytophthora infestans)*		7 to 21 °C	Rainfall above 0.1 mm	Fahim *et al.*, 2007
Potato	**Late blight of Potato** *(Phytophthora infestans)*		7 to 21 °C	Rainfall above 0.1 mm	Fahim *et al.*, 2007

Table 3 Severity classification of achieving the favorable weather conditions for diseases

Class	Achieving the favorable weather conditions for diseases in each crop season (%)
No	0
Low	0 - 25
Moderate	25 - 50
High	50 - 75
Extreme	75 - 100

Future Climate data

The future climate data has been obtained from the downscaling process on global climate model (ECHAM6) of scenario Representative Concentration Pathways RCP 4.5 by a horizontal resolution 50 km using regional climate model (RegCM 4). The climate parameters have been exported and analyzed from 2010 up to 2090 for the determined Governorates to study the expected probability of crops infection by the determined diseases.

RESULTS

Assessing the plant diseases have been done based on studying the availability of favorable weather conditions for crops infection according to the expected future climate data, and frequency/intensity of this availability in the studied areas for the determined crops. The results of each decade (10 years) have been collected to studying the impact on infections with time.

Late wilt of maize

The availability of the favorable weather conditions for the late wilt disease during the maize growing season from 2011 up to 2090 has been studied for the determined Governorates. Figure (1) shows the number of achieving the favorable weather conditions for the infection by late wilt disease in each 10 years and it's observed that, the highest infections will be in Lower Egypt Governorates followed by Middle and Upper Egypt Governorates, and Monufia Governorate is the highest of them while the lowest one is Sohag governorate. And it is worth to mentioning that there is an extreme increment in infection number at Minya Governorate during (2061-2070) period even it exceeds than Sharqia Governorate in Lower Egypt.

Also it's observed that the infection rate tend to increase in the future at Middle and Upper Egypt Governorates while in Lower Egypt the infection tend to decrease.

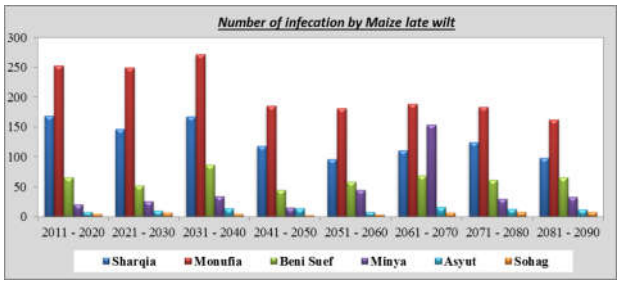

Figure 1 The availability of favorable weather conditions for infection by late wilt of maize in a determined Lower, Middle, and Upper Egypt Governorates.

Figure (2) shows the total number of infected years by late wilt of maize for the studied Governorates during the study period and table (4) shows the percentage of those years according to severity disease classification during the study period for the specified Governorates and it has been found that, all study years in Lower Egypt Governorates and Beni Suef Governorate in Middle Egypt have favorable weather conditions for infection and although the tendency of upper Egypt to increase in the future, it have 48 % and 66% in Asyut and Sohag from their study years don't meet the favorable weather conditions for infection.

And as shown from table (4) Sohag Governorate has the lowest infection years where about two third of their study years under non-severity class and most of remaining years were found in the low class while the highest percentage of infected years in high, and extreme class was found in Monufia Governorate.

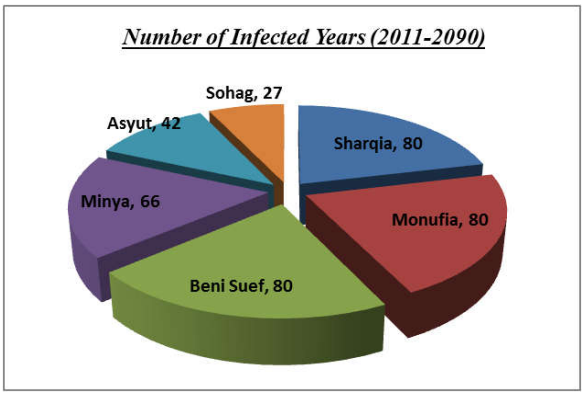

Figure 2 The total number of infected years by late wilt of maize in a specified Lower, Middle, and Upper Egypt Governorates.

Table 4 Severity classification (%) of studied years to the favorable weather conditions availability of by late wilt of maize disease.

Severity Class	Sharqia	Monufia	Beni Suef	Minya	Asyut	Sohag
No	0	0	0	18	48	66
Low	38	19	64	60	35	21
Moderate	53	45	26	14	13	10
High	8	24	8	5	4	1
Extreme	3	13	3	4	1	1

Leaf rust of wheat

The availability of the favorable weather conditions for infection by leaf rust disease during wheat growing season from 2011 up to 2090 has been studied for the determined Governorates. Figure (3) illustrates the availability of favorable weather conditions for the infection by leaf rust and it's observed that, the highest infections will be in Lower Egypt Governorates followed by Middle and Upper Egypt Governorates. Also it's observed that, Beheira Governorate is the highest of them while the lowest one is Asyut, and it has been worth to mention that Minya Governorate has an extreme increase in the availability of favorable weather conditions to leaf rust of wheat during (2061-2070) period even it was the highest record observed in all studied governorates during all study period. Also it's observed that the infection rate by leaf rust tend to increase with time at all studied Governorates.

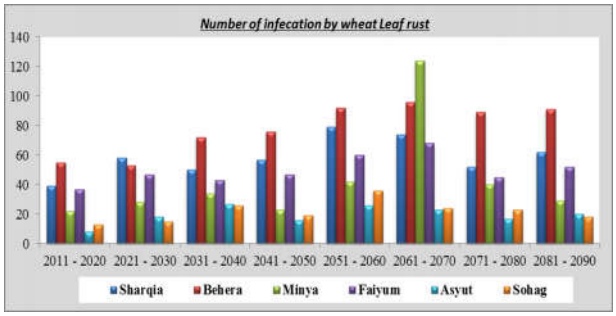

Figure 3 Number of infection by leaf rust of wheat according to the favorable weather conditions during the study period in a determined Lower, Middle, and Upper Egypt Governorates.

Figure (4) shows the total number of infected years by leaf rust of wheat for the studied Governorates during the study period and table (5) shows the percentage of study years to severity classifications in availability of favorable weather conditions to wheat leaf rust disease in the determined Governorates and it has been found that, the favorable weather conditions for infection are available on only Faiyum Governorate during all study years but, although this, the highest percentage of infected years in high and extreme classes observed in Sharqia Governorate while the lowest percentage observed in Asyut Governorate and about 70% of their studied years under non and low severity classes.

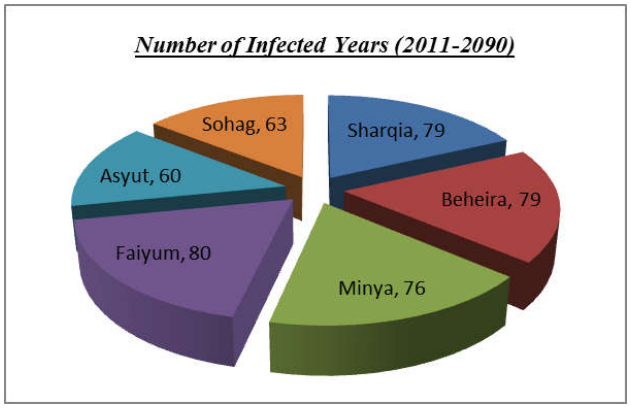

Figure 4 The total number of infected years by leaf rust of wheat in a studied Lower, Middle, and Upper Egypt Governorates.

Table 5 Severity classification (%) of studied years to the favorable weather conditions availability of wheat leaf rust disease.

Severity Class	*Sharqia*	*Beheira*	*Minya*	*Faiyum*	*Asyut*	*Sohag*
No	1	1	5	0	25	21
Low	35	30	63	49	45	39
Moderate	49	53	20	41	20	34
High	10	14	8	8	8	5
Extreme	5	3	5	3	3	1

Chocolate leaf spot of faba bean

The availability of the favorable weather conditions for infection by chocolate leaf spot disease during faba bean growing season from 2011 up to 2090 has been studied for the determined Governorates. Figure (5) illustrates the availability of favorable weather conditions for the infection by chocolate leaf spot in each 10 years and it's observed that, the highest infection will be in lower Egypt Governorates and in the first 50

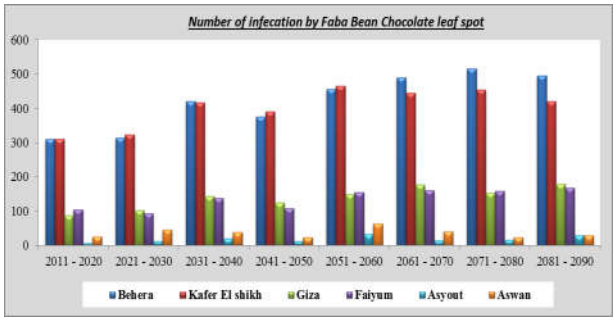

Figure 5 Number of infection by chocolate leaf spot of faba bean during the study period in a determined Lower, Middle, and Upper Egypt Governorates.

years (2011-2060) the conditions achieved in Kafr El sheikh slightly more than Beheira Governorate while by the period of (2061-2070) the antithesis was observed and the favorable conditions for infection achieved in Beheira more than Kafr El sheikh Governorate. Middle Egypt followed by Upper Egypt Governorates came in the next rank after Lower Egypt in the infection chances.

Figure (6) shows the total number of infected years by chocolate leaf spot of faba bean for the determined Governorates during the study period and table (5) shows the percentage of study years to severity classifications in availability of favorable weather conditions to faba bean chocolate leaf spot disease in the determined Governorates and it has been found that, the favorable weather conditions for the infection were available during all study years in Lower and Middle Egypt Governorates while in Upper Egypt it's found 30% and 8% of study years under non-severity class in Asyut and Aswan governorates respectively. Also it's observed that Kafr El sheikh has the highest percentage in high and extreme classes while Aswan has the lowest percentage in these classes.

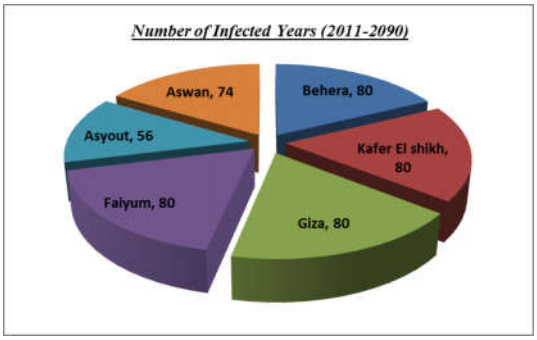

Figure 6 The total number of infected years by chocolate leaf spot of faba bean in a studied Lower, Middle, and Upper Egypt Governorates.

Table 6 Severity classification (%) of studied years to the favorable weather conditions availability of faba bean chocolate leaf spot disease

Severity Class	Beheira	Kafr El sheikh	Giza	Faiyum	Asyut	Aswan
No	0	0	0	0	30	8
Low	11	6	38	25	41	65
Moderate	46	30	44	41	23	23
High	34	46	14	23	5	4
Extreme	9	18	5	11	1	1

Late blight of tomato

The availability of the favorable weather conditions to late blight disease during the tomato growing season from 2011 up to 2090 has been studied for the determined Governorates. Figure (7) illustrates the availability of favorable weather conditions for the infection by tomato late blight in each 10 years and it's observed that, the highest infection will be in Lower Egypt Governorates followed by Middle and Upper Egypt Governorates, and Ismailia Governorate is the highest one during the study period while the lowest infection is observed in Qena Governorate among the study area. Also it has been worth to mentions that the chance for infection will decrease with the time in Lower and Middle Egypt Governorates while in Upper Egypt it will increase.

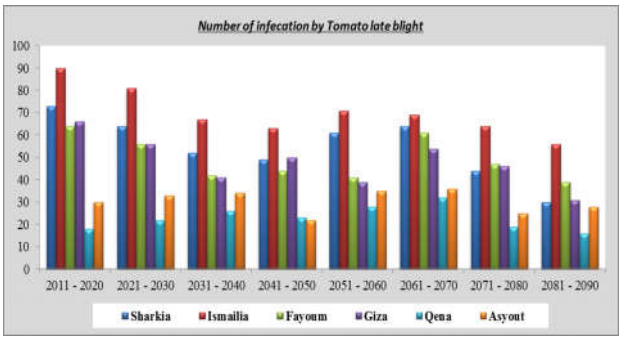

Figure 7 The availability of favorable weather conditions for infection by late blight of tomato in a specified Lower, Middle, and Upper Egypt Governorates.

Figure (8) shows the total number of infected years by tomato late blight for the determined Governorates during the study period and it has been found that, all studied years in Lower and Middle Egypt Governorates have favorable weather conditions for infection and although the tendency of upper Egypt to increase in the future, it have from 8 to 19 years of study period don't meet the favorable weather conditions for infection.

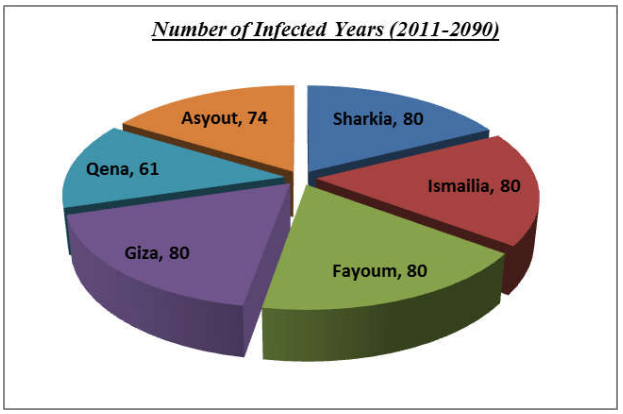

Figure 8 The total number of infected years by tomato late blight in a studied Lower, Middle, and Upper Egypt Governorates.

The percentage of study years to severity classifications in availability of favorable weather conditions to tomato late blight disease in the determined Governorates is shown in table (7) which indicated that, Qena Governorate has the lowest infection years where about 24 % of their study years under non- severity class and most of remaining percentage in the low class while Ismailia Governorate has the highest infection years, but although this, the highest Governorate in high and extreme classes was Faiyum Governorate**.**

Table 7 Severity classification (%) of studied years to the favorable weather conditions availability of tomato late blight disease

Severity Class	Sharqia	Ismailia	Faiyum	Giza	Qena	Asyut
No	0	0	0	0	24	8
Low	46	33	34	50	40	40
Moderate	34	49	36	39	20	40
High	11	14	21	9	8	8
Extreme	9	5	9	3	9	5

Late blight of potato

The availability of the favorable weather conditions for the infection by late blight during the potato growing season from 2011 up to 2090 has been studied for the specified Governorates. Figure (9) shows the availability of these favorable weather conditions for the infection and it's observed that, the highest infections will be in Lower Egypt Governorates followed by Middle and Upper Egypt Governorates, and Beheira Governorate has the highest records during all studied periods except in (2081-2090) period where the highest record in this period has been observed at Dakahlia Governorate while Aswan Governorate was the lowest one during all study period. Also it's observed that, the infection rate tend to increase in the future in Upper Egypt Governorate while in Lower and Middle Egypt the infection tend to decrees because the wet condition expect to decrees in the future in this governorates.

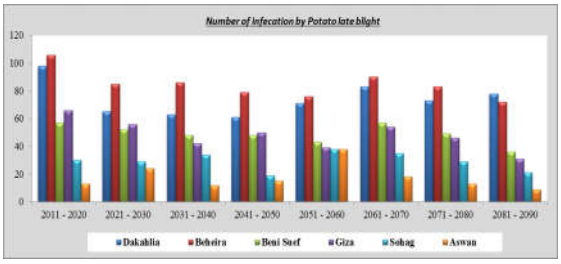

Figure 9 The availability of favorable weather conditions for infection by late blight of potato in a specified Lower, Middle, and Upper Egypt Governorates.

Figure (10) shows the total number of infected years by late blight of potato for the studied Governorates during the study period and table (8) shows the percentage of study years to severity classifications in availability of favorable weather conditions to potato late blight disease in the determined Governorates and it has been found that, all study years in Lower Egypt Governorates and Giza Governorate in Middle Egypt have the favorable weather conditions for Potato infection and, although the tendency of upper Egypt to increase in the future, it have 10% in Sohag and 25% and Aswan from their study years don't meet this conditions for infection. And as observed from table (8), Aswan Governorate has the lowest infection years where about 25 % of their study years under non- severity class and about 50 % in the ***Low class*** while the highest percentage of infected years in high, and extreme classes was found in Dakahlia Governorate.

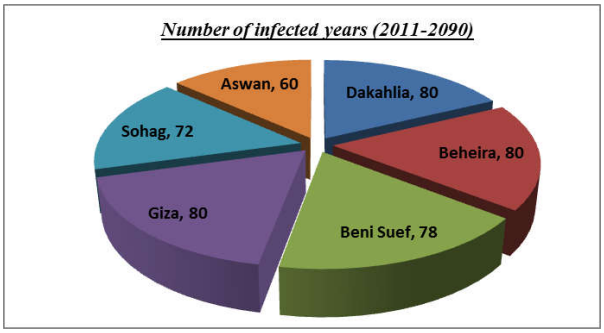

Figure 10 The total number of infected years by late blight of potato in a specified Lower, Middle, and Upper Egypt Governorates.

Table 8 Severity classification (%) of studied years to the favorable weather conditions availability of potato late blight disease

Severity Class	Dakahlia	Behera	Beni Suef	Giza	Sohag	Aswan
No	0	0	3	0	10	25
Low	36	28	30	50	53	49
Moderate	39	59	53	39	30	23
High	16	11	13	9	6	1
Extreme	9	3	3	3	1	3

DISCUSSION

The results of this study have been agreed with different studies, such as, Junk *et al*, (2016) who reported that positive trends in favorable wheat leaf rust infection conditions occur more than the reference period due to projected climatic conditions, and Abolmaaty (2006) indicated that the severities of current cultivars of wheat to leaf rust caused by *Puccinia triticina* also will increase with increasing temperature, which is projected under climate change conditions. Also Hassan (2016) reported that the influence of climate change on severity of foliar diseases infesting faba bean in some governorates in Egypt will increase under climate change. The higher temperatures, for some crops will become more susceptible to plant diseases because of the reduced number of frost days that normally prevent the over-wintering of pathogens. Garrett and Cox (2006) studied the impact of climate change on potato late blight risk and found that, the late blight risk for current potato production regions in compared with the periods of 2040-2060, will increase by 10-15%. Late blight diseases is appear in a specific temperature range within high moisture weather a conditions which are expected to decrease in Lower and Middle Egypt in the future and increase in Upper Egypt.

CONCLUSION

Finally, plant disease which have been assessed based on the favorable weather conditions for infection of a specified crops and the results indicated that, the availability of the favorable weather conditions for infection was the highest in Lower Egypt followed by Middle and Upper Egypt Governorates, and the infection rate tend to increase in the future except in the diseases which depend on wet condition where this condition will decrease in the future at Lower and Middle Egypt Governorates but it will do in Upper Egypt Governorates. Now, emphasis must shift from impact assessment to developing adaptation and mitigation strategies and options. First, there is need to evaluate under climate change the efficacy of current physical, chemical and biological control tactics, including disease resistant cultivars, and secondly, to include future climate scenarios in all research aimed at developing new tools and tactics.

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