Acta Scientific AGRICULTURE (ISSN: 2581-365X)

Volume 6 Issue 3 March 2022

Research Article

Impact of Climate Variability on Groundnut Rust (*Puccinia arachidis* Speg.) at Hot Semi-Arid Region of Gujarat

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Received: February 17, 2022

Published: February 24, 2022

Abstract

Severity of groundnut rust disease caused by pathogen *Puccinia arachidis* Speg was studied over eight *kharif* seasons between 2010 and 2020 at Junagadh located in hot semi-arid eco region under agro climatic zone of Gujarat plains and hills. Rust severity was measured on five cultivars (GG 20, GJG 22, TG 37A, TLG 45 and Western 66) grown during three sowing periods (May II fortnight, first and second fortnights of June). Climatic variability for the *kharif* period of groundnut cultivation was quantified for three climatic variables viz*.,* temperature (maximum and minimum) and rainfall so as to relate to rust severity. The rust progressions in respect of seasons aggregated over cultivars and sowing time on calendar and crop age basis indicated varying duration and severity of the disease. Mean rust severity differed significantly across seasons, cultivars and sowing periods. The rust severity was significantly higher in 2011, GJG 22 and June (both first and second fortnight) sowings, respectively. Although the progression of rust severity varied on calendar as well as crop age basis amongst cultivars, the disease commencement in respect of sowing times was during 34th standard meteorological week (third week of August) coinciding with crop age of eight weeks. Magnitude of climatic variability worked out for *kharif* of 2011-2020 over long term normals (40 years' average) indicated a significant change in respect of maximum temperature (+ 0.7 °C) and rainfall (+16.9 mm/week). The significant impact of climatic variability on rust severity over seasons indicated positive and negative association of the unchanging minimum temperature and increasing rainfall, respectively. Climate variability impacts on rust severity brought out CJG 22 and TLG 45 as climate resilient cultivars, and sowing groundnut during second fortnight of May as an adaptive practice for recommendation to farmers under the current climate change scenario.

Keywords: Climate variability; Cultivar; Groundnut; Gujarat; Sowing period; Rust

Introduction

Climate in terms of increased temperature, rising atmospheric CO_2 level and changing precipitation patterns have significant impacts on all components of agriculture including diseases. The compounding effects of climate change are manifested not only on crop production and food price, but also on nutrition and hunger across the world [1-2] and India is not an exception. Negative impacts of changing climate outweighing positive ones on global crop production were reported [3]. Relationship between environment and crop diseases suggests that climate change would cause modifications in host pathogen relationships. It is also well known that other system variables such as varietal selection and agronomic practices influence the manifestation of diseases. Under the changing climate, much of Brazil, India and Southeast Asia were predicted to have decline in crop diseases [4]. However, disease epidemics have been on rise in India in recent years [5] and there is a need to understand the impact of climate change on host pathogen interaction to outline appropriate management strategies.

Groundnut (*Arachis hypogaea*, L.), also known as peanut is widely cultivated throughout tropical, sub-tropical and warm temperate climatic zones of the world [6]. India grows groundnut as a principal oil seed crop across varying agro-climatic environments in 4.81 mha with a production of 6.69 mt [7]. Gujarat is the leading groundnut producer (2.2 mt) from an area of 1.59 mha contributing 32.7% of the country's production. Major area (83%) of groundnut is rainfed (post monsoon season) with the period cultivation between June/July and October/November and the remaining 17% grows the crop under irrigated conditions during October-March [8]. With more than 150 varieties of groundnut released in India for different agro ecological situations, the cultivars often grown in Gujarat include GG-20, TAG-24, TG-37-A, TG-38, TPG-41, GG-2 and GAUG-10 with their sowing time dependent on the onset of monsoon. The sowing methods range from line or crisscross sowing on flat -bed system or broad bed and furrow system or ridge and furrow system with their spacing varying depending on the cultivars being bunchy or spreading or semi spreading or runner types [9]. The *kharif* groundnut is often grown with low input use and high pressure of insect-pests including weeds leading to low productivity. Hence, it becomes imperative to decipher the effects of various factors affecting progression of a disease to assess the impact of changing climate.

Among groundnut diseases, rust (*Puccinia arachidis* Speg.) and tikka leaf spot (*Cercospora* spp.) together cause 50-70% reduction in pod yield and reduce quality and digestibility of haulms up to 22% [10-11]. Rust damage symptoms associated with early crop growing season lead to early pod maturity, reduced seed size, increased pod senescence and decreased oil content. Most severe rust infections cause ~ 57% economic losses. Available literature suggests that the rust progression was favored by temperature range of 20 to 30°C and humidity above 78% [12] with slow progress at 10°C or less and above 35°C [13]. Modelled climate change projections for 2050 had shown ~2.3 to 43.2% change in groundnut yields across various regions of India [14]. A decrease in yield by 20 to 34% during 2071-2100 owing to air and soil temperatures above optimum was indicated for Rajkot, Bhavanagar, Kesod and Bhuj districts of Gujarat [15]. Present study investigates the status and dynamics of rust on groundnut in addition to effect of cultivars, and sowing periods and impact of quantified climatic change for the second decade of the twenty first century at Junagadh (Gujarat) at hot semi-arid agro ecology of the agro climatic zone of Gujarat Plains and Hills.

Materials and Methods

Observations of rust severity on groundnut at Junagadh (Gujarat) [21°:31':00" N; 70°:33':00" E] were part of studies on pest dynamics in relation to climate change during *kharif* 2011-20 (excluding 2017 and 2018) under the national flagship programme on National Innovations in Climate Resilient Agriculture (NICRA). Twenty farmer fields across 10 villages accounting a minimum of one-acre per field were considered for sampling rust severity at weekly intervals following disease appearance till harvest during each study season. Although more than 10 cultivars were grown at anyone season by different farmers, the common cultivars grown during the study seasons accounted were GG 20, GJG 22, TG 37A, TLG 45 and WESTERN 66. Sowing periods varied over years between May II fortnight (May II FN) and June II fortnight (June II FN). Groundnut production practices such as fertilizer applications, deweeding and need based insect pest management were adhered by farmers based on recommended standard package of practices of the state. Five spots per field were sampled for rust during each season with observations of disease grade on three out of ten plants per spot based on 1-9 scale. Per cent severity of rust for each spot and of each field was calculated using the formulae [16] as given below.

Severity grade per spot (S_i)

$$S_i = 100 \times \sum_{j=0}^{J} \frac{j \times y_{ij}}{3 \times J}|$$

Severity grade per field (S_f)

$$S_f = 1/I \times \sum_{i=1}^{I} S_i$$

where, i = spot no, I = 1,2, 5; j = severity grade, j = 0,1, 9; J = maximum disease grade; I=total number of spots; Yij = number of plants in ith spot with jth severity grade. Mean severity across five spots per field for a given week of observation was calculated for individual fields. Data sets on progression of disease amongst sampled fields of eight seasons (2011-16 and 2019-20) along standard meteorological weeks (SMW) were compiled. Data sets were assembled on the rust progression pertaining to individual fields in respect of cultivars (GG 20, GJG 22, TG 37A, TLG 45 and WESTERN 66) and periods of sowing grouped into three *viz.,* May second fortnight (May II FN), June first fortnight (June I FN) and June second (June II FN). Disease progression along SMWs in relation to different study seasons, cultivars and sowing periods was calculated and represented graphically. Differences in rust severity (%) across seasons, cultivars and sowing periods were tested using one-way ANOVA following arcsine transformation of data sets based on per cent rust severity on disease dynamics of study seasons with their means compared using Duncan Multiple Range Test (DMRT).

Data on weather variables *viz.,* maximum and minimum temperature (MaxT and MinT in °C) and rainfall (RF in mm/week) were gathered for study seasons from the meteorological observatory of Directorate of Groundnut Research, Junagadh (GJ). Climatic normals (40 years' average: 1980-2010) in respect MaxT (°C), MinT (°C) and RF (mm/week) on SMW basis pertaining to periods of disease observations (34-44 SMWs) for Junagadh (GJ) were obtained from the All India Coordinated Research Project on Agrometeorology, Central Institute for Dryland Agriculture, Hyderabad. Climatic deviations for all individual study seasons (2011-16 and 2019-20) in respect of weather variables (MaxT, MinT and RF) was worked out as differences between values of actual/prevalent weather and climatic normal corresponding to SMWs of *kharif* groundnut (22-45 SMW) of the study location. Student 't' test with equal variances was used to quantify the magnitude of climatic variability for MaxT, MinT and RF considering 'actual' and 'normal' data sets of study periods. Kendall's correlation coefficients ('*tau'*) were worked out between climatic deviations (difference of actual values from 'normals') of MaxT, MinT and RF and rust severity for the aggregate of study seasons and for data sets segregated along cultivars and sowing periods. All the statistical analyses (ANOVA, 't' test and Kendall's correlations) were done using SAS 9.4 [17].

Results and Discussion

Dominant role played by weather in determining disease status at a given point in time and over long term getting manifested in terms of yield of crops and the evolution of pathogens, respectively at a given location is a natural phenomenon. Study on progression of diseases along with documentation of weather conditions over many seasons offered scope to assess the impact of changing climate in terms of weather variability and/or their extremes on the crop-disease interactions. Present study has been a part of larger scheme implemented for assessing the impact of climate variability/change based on systematic surveillance plan and standard sampling procedures capturing both biotic as well as abiotic interactions, simultaneously. It is to be mentioned that *kharif* seasons of 2017 and 2018 were not part of the study due to the inadvertent circumstances combined with lack of human resources although rust occurrences were seen. Considering the fact that groundnut sowings were taken up not only at different periods in respect of different seasons but also within a given season among different fields, the disease appearance varied across seasons drastically. Therefore progressions were visualized both on calendar and crop age basis in respect of seasons, cultivars and sowing periods as the later approach brought the comparison on a common scale.

Seasonality of rust severity

Rust symptoms appeared at 34 SMW during 2013, 2014 and 2020 and during later weeks of 37, 38 39 and 40 SMW in respect of 2019, 2015, 2011-2012 and 2020. While maximum severity of 84.4% at 42 SMW in 2012 followed by 78.5% at 39 SMW in 2011 were noted, 2015 had a severity around 20% at all times. The differing rates of disease progression was evident across seasons based on the slope of lines. Seasons 2011 and 2016 had rust occurrence till 44 SMW irrespective of the dynamics along cultivars and sowing periods. Inter seasonal analysis of rust severity indicated significantly higher mean in 2011 followed by 2012 over all other later study seasons (Figure 1). The rust commencement varied across seasons with a range of 8 to 14 weeks after sowing (WAS) with early commencement coinciding with 2020 and the late appearance during 2011, 2015 and 2016. While 2012 had a steep progression between 17 and 84% in respect of 12 and 15 WAS, late season high severity (45-67%) was noted between 13 and 21 WAS in 2011, the seasons that had the highest severity over all other seasons. In addition to the high rust severity seasons of 2011 and 2012, 2020 alone had more than 50% at any age or stage of crop growth (Figure 2). Rust severity between 2013 and 2020 was on par and significantly higher over 2014 and 2015. However, the seasons of 2016 and 2019 had rust severity not only statistically on par between themselves but also on par with other four seasons (2013-2015 and2020) other than 2011 and 2012 (Figure 3).

Rust severity in relation to cultivars

Rust appearance was early and simultaneous on GG 20, TLG 45 and Western 6 during 34 SMW. The disease initiated during 35 and 36 SMWs in respect of TG 37A and GJG 22. The terminal severity also differed among cultivars being early for Western 66 (40 SMW) followed by GJG 22 and LG 45 (42 SMW), TG 37A (43 SMW) and GG

20 44 SMW) (Figure 4). It was highly obvious that the dynamics of rust progression was earliest in respect of Western 66 followed by GG20. The window of commencement of rust over the seasons for cultivars irrespective of periods of planting ranged from eight to eleven WAS. Although the terminal severity was the highest for GG 20, the late commencement and steep progression relevant to GJG 22 had led to the significantly higher rust status on the later cultivar (Figure 5). Mean rust severity was significantly higher for GJG 22 (40.6%) over all other four cultivars viz., GG20, TG37A, TLG 45 and Western 66 which were on par (Figure 6). Differential susceptibility of cultivars to rust at any one given time could be the reason over and above the seasonal and/or sowing period effects as all cultivars belonged to the medium maturity group with duration of 110-115 days [18-20].

Figure 1: Progression of rust along seasons - calendar based.

Figure 2: Progression of rust along seasons- crop age based.

Figure 3: Status of rust on *kharif* groundnut over seasons.

Figure 4: Progression of rust in relation to cultivars - calender based.

Figure 5: Progression of rust in relation to cultivars - crop age based.

Figure 6: Status of rust on groundnut in relation to cultivars and periods of planting.

Rust severity in relation to sowing periods

May IIFN sowing had shown lesser and shorter period of disease progression (34-41 SMW) of rust severity although commencement of disease was similar at 34 SMW (Figure 7). With each fortnight delay in sowing period of groundnut, the commencement of occurrence was delayed by a fortnight indicating start of the disease at the crop age of eight weeks from the planting time (Figure 8). However, mean severity was significantly lesser with the early planting (May IIFN) (19.3%) over June plantings that were on par (refer Figure 6).

Figure 7: Progression of rust in relation to sowing periods - calendar based.

Magnitude of climatic variability

The magnitude of climate variability worked out for Junagadh (Gujarat) for the *kharif* seasons of study period indicated a significant rise of maximum temperature (MaxT) by 0.7°C and of rainfall (RF) by 16.9 mm/week with no change for minimum temperature (MinT) (Table 1; Column 3). It is to be mentioned that the magnitude of climatic variability worked out for 2011-16 seasons using same normals (long term average of 1980-2010) used in the present study indicated a similar pattern of change till 2020 with variability in respect of MaxT, MinT and RF as 0.63°C ($p < 0.05$), -0.45 (NS) and 12.4mm/week ($p < 0.001$), respectively [21].

Figure 8: Progression of rust in relation to sowing periods - crop age based.

Climatic variables	**Actual mean (2011-20)**	**Magnitude of climate variability**$^{\#\$}$	**Kendall's '*tau*' coefficients** $^{\$}$
Max. T (°C)	33.6	0.70**	-0.03
Min.T (°C)	24.4	-0.17 ^{NS}	0.28***
RF (mm/week)	46.2	16.9 **	-0.10**

Table 1: Magnitude of climate variability and its impact on rust severity over seasons.

$^{\#}$: quantified based student 't' test between actual values of climatic variables and their corresponding normals on SMW basis over study seasons $^{\$}$: significance denoted by **: $p < 0.01$; ***: $p < 0.001$; ^{NS}: not significant.

Impact of climatic variability on rust severity

The associational analysis of rust dynamics aggregated over all study seasons *vis a vis* the climatic deviations of MaxT, MinT and RF indicated significant and positive association with an unchanging MinT and a significant decline due to significantly increased RF, in general, irrespective of the effects of cultivars and sowing periods (Table 1; Column 4). The response of cultivars and sowing periods to the observed climatic variability varied and none of it reflected the pattern of general effect over seasons (Table 2). While impact of climatic variability was absent on rust severity in relation to cultivars (GJG 22 and TLG 45), the unchanging MinT had a significantly decreasing effect on rust severity of GG 20, TG 37A and Western 66. However, an increasing MaxT had shown positive and negative impacts that were significant for rust occurrence on CG 20 and TG 37A, respectively indicating the differential responses of cultivars to climate variability. A significant and positive association of the rust severity with increased RF was noted on *cv.* TG37A and Western 66. With regard to sowing periods, early planting (May IIFN) did not show climatic variability impacting rust severity. For June IFN sowing, the impact of MinT was significantly negative and was non-significant for the June IIFN sowing. Significantly decreasing and increasing rust severity in respect of MaxT and RF were noticed for the sowing period of June IIFN (Table 2). The varied patterns were noted for the impact of climatic variability on rust severity over seasons, cultivars and sowing periods clearly pointed to the complex interactions of the cultivar-disease- production practices influenced by the observed climatic variability/change. Nevertheless, the suitability of GJG 22 and TLG 45 and sowing during second fortnight of May emerged as the climate resilient cultivars and sowing time, respectively.

Particulars	Kendall's '*tau*' coefficients $		
	Max. T (°C)	Min.T (°C)	RF (mm/week)
Cultivars			
GG 20	0.10*	-0.35***	-0.04 ^{NS}
GJG 22	-0.11 ^{NS}	-0.09 ^{NS}	0.18 ^{NS}
TG 37A	-0.24*	-0.25*	0.43***
TLG 45	-0.12 ^{NS}	-0.13 ^{NS}	0.16 ^{NS}
Western 66	-0.09 ^{NS}	-0.39*	0.29*
Sowing periods			
May II FN	0.09 ^{NS}	0.16 ^{NS}	-0.10 ^{NS}
June I FN	0.06 ^{NS}	-0.44***	-0.006 ^{NS}
June II FN	-0.19**	-0.08 ^{NS}	0.32***

Table 2: Impact of climate variability on rust severity in relation to cultivars and sowing periods.

$: significance of association between rust severity and climatic variables worked out using '*tau*' coefficients denoted by *: $p < 0.05$; **: $p < 0.01$; ***: $p < 0.001$; ^{NS}: not significant.

Conclusion

Prevalence of rust disease on *kharif* groundnut cultivars was regular at hot semi eco region of Gujarat plains and Hills with sowing periods spread between May II fortnight and June end. Seasonal variations of rust severity were more pronounced across years over cultivars and sowing times. Climate variability/change occurred during the *kharif* groundnut cultivation in the region of Junagadh (Gujarat) and its impact on rust severity manifestation at field level was also statistically obvious. Non-significant impact of climate variability on rust severity over eight seasons on cultivars GJG 22 and TLG 45 resulted in designating these cultivars as climate resilient. The absence of impact of climatic variability on rust severity for May second fortnight sowing also indicated that an early (May IIFN) sowing as an adaptive practice towards changing climate. It is to be mentioned that study accounted the overall (many seasons) as well as specific (cultivar and sowing time) relations to climate variability on rust disease of groundnut. A scrutiny into the morphological, cultural and biochemical characteristics of the rust pathogen would add to the evolving response of pathogen *per se* to the climatic variability. The current study would serve as a platform to compare the changing dynamics of rust in future years of the same region. Similar methodology could be extended for other diseases of the same region and/or for other agro ecologies so as to understand the impact of climate change on many diseases and locations, respectively.

Acknowledgements

All authors sincerely thank the contributions of field scouts engaged in data collection at the Directorate of Groundnut Research, Junagadh (Gujarat) during study periods. The project funding under the programme of 'National Innovations in Climate Resilient Agriculture' funded by Indian Council of Agricultural Research, Government of India is also gratefully acknowledged.

Conflict of Interest

Authors do not have any conflict of interest.

Bibliography

1. Nelson Gerald C., *et al*. "Climate change effects on agriculture: Economic responses to biophysical shocks". *Proceedings of the National Academy of Sciences* 111.9 (2014): 3274-3279.

2. Pingali P., *et al*. "Managing climate change risks in food systems". *Transforming Food Systems for a Rising India*. Palgrave Macmillan, Cham (2019): 241-275.

3. Muller C. “African lessons on climate change risks for agriculture”. *Annual Review of Nutrition* 33 (2013): 395-411.

4. Chaloner Thomas M., *et al*. “Plant pathogen infection risk tracks global crop yields under climate change”. *Nature Climate Change* 11.8 (2021):710-715.

5. Chowdappa P. Impact of climate change on fungal diseases of horticultural crops. “*Challenges of Climate Change-Indian Horticulture. Westville Publishing House, New Delhi* (2010). New Delhi. 144-151.

6. Sogut T., *et al*. “Effect of sowing time on peanut (*Arachis hypogaea* L.) cultivars: II. Fatty acid composition”. *Agriculture and Agricultural Science Procedia* 10 (2016): 76-82.

7. Anonymous. “Agricultural statistics at a glance 2019. Government of India. Ministry of Agriculture and Farmers Welfare”. Department of Agriculture Cooperation and Farmers Welfare Directorate of Economics and Statistics. (2019): 315.

8. Singh P., *et al*. “Potential benefits of drought and heat tolerance in groundnut for adaptation to climate change in India and West Africa”. *Mitigation and Adaptation Strategies for Global Change* 19.5 (2014): 509-529.

9. Thirumalaisamy PP., *et al*. “Status of groundnut early leaf spot (*Cercospora arachidicola*) at hot semi-arid ecoregion of Gujarat (India): past, present and future”. *Acta Scientific Agriculture* 5.8 (2021): 48-52.

10. Pande S., *et al.* “Disease management factors influencing yield and quality of sorghum and groundnut crop residues”. *Field Crops Research* 84.1-2 (2003): 89-103.

11. Singh, Maninder P., *et al*. “Late leaf spot effects on growth, photosynthesis and yield in peanut cultivars of differing resistance”. *Agronomy Journal* 103.1 (2011): 85-91.

12. Mondal Suvendu and AM Badigannavar. “Peanut rust (*Puccinia arachidis* Speg.) disease: its background and recent accomplishments towards disease resistance breeding”. *Protoplasma* 252.6 (2015): 1409-1420.

13. Rao A., *et al*. Effect of temperature on rust and leaf spot disease development in groundnut”. *Journal of Oilseeds Research* 14.2 (1997): 249-255.

14. Kadiyala MDM., *et al*. “Modeling the potential impacts of climate change and adaptation strategies on groundnut production in India”. *Science of the Total Environment* 776 (2021): 145996.

15. Gangurde Sunil S., *et al*. “Climate-smart groundnuts for achieving high productivity and improved quality: In. Current status, challenges, and opportunities”. *Genomic Designing of Climate-Smart Oilseed Crops*. Springer, Switzerland AG. C. Kol (ed.) Cham, (2019): 133-172.

16. Vennila S., *et al*. “Effect of climatic variability and weather factors on development of tomato early blight in a hot semi-arid region of Southern India”. *Indian Journal of Horticulture* 77.2 (2021): 333-338.

17. Anonymous. “Strengthening statistical computing for NARS (platform for statistical computing)”. (2018).

18. Kumar N., *et al*. “Improved and popular groundnut varieties recommended for Gujarat”. *ICAR-Directorate of Groundnut Research* (2015): 1-4.

19. Anonymous. “Status paper on Groundnut”. (2017). https://nmoop.gov.in/publication/status_paper_on_nuts2017.pdf

20. Anonymous. “Western seeds LTD”. https://www.westernagriseeds.com.

21. Anonymous. “ICAR-NCIPM Annual Report 2020”, New Delhi 97-99 (2020): 1-97.