Homoclime analysis of chickpea and its implications to Queensland’s chickpea industry

Yash Chauhan, Graeme Wright, NageswaraRao C. Rachaputi and Kevin McCosker

Queensland Department of Primary Industries and Fisheries, Agency for Food and Fibre Sciences, Farming Systems, J. Bjelke Petersen Research Station, PO Box 23, Kingaroy, Qld 4610
www.dpi.qld.gov.au Email: yash.chauhan@dpi.qld.gov.au

Abstract

Homoclime analysis is a method used to identify locations with similar climatic conditions. In this study we used this approach to identify opportunities for the better targeting of introduction of chickpea (*Cicer arietinum* L.) germplasm from India into Queensland, Australia. The analysis involved clustering of climate profiles from 39 Australian locations from latitudes over 14 to –36?S and 29 locations in India spread over 12 to 32?N during the chickpea growing season. All locations from both countries could be clustered into four groups on the basis of maximum and minimum temperatures, and day length. Locations within a cluster were defined as being a homoclime with each other. Locations from central Queensland and central India were clustered into one group, locations from northern Australia and peninsular India into a second cluster and locations from southern Queensland and northern India into a third cluster. A fourth cluster consisting of most of the southern Australian locations did not cluster with any of the Indian locations. The analysis revealed that all Queensland locations studied had homoclimes in India, which suggests there may be good scope to introduce promising Indian chickpea cultivars from each of the respective homoclimes.

Media summary

A novel homoclime approach has identified scope for targeting introduction of high yielding chickpea lines adapted to hot and dry environments from India into Queensland.

Key words

Adaptation, environments, cluster analysis

Introduction

Homoclimes are locations with similar climatic conditions. Identification of a homoclime can greatly assist in the introduction of crops from one region into another, as those crops would be experiencing similar climatic conditions in the new region as found in their original habitat. Chickpea (*Cicer arietinum* L.) is a promising commercial crop in Queensland, Australia, however the state depends on other breeding programs within and outside Australia for introduction of new high yielding cultivars. Warm temperatures, terminal drought, relatively short growing season and low severity of *Ascochyta* blight characterize chickpea growing regions in central and southern parts of Queensland, which are significantly different from other chickpea production regions of Australian (Siddique, and Sykes 1997). India has long been considered as a secondary centre for diversity of desi chickpea and there is a large collection of desi and kabuli chickpea cultivars that is reputedly adapted to hot and dry climatic conditions (Malhotra et al., 1987). As chickpea is grown in India from latitudes between 10^{o} and 32^{o}N, some of the regions could be the appropriate homoclimes for chickpea growing areas in Queensland. The purpose of this investigation was to identify homoclimes of locations in Queensland amongst those of chickpea growing regions of India to assist in the future targeting of chickpea germplasm.

Materials and Methods

This homoclime analysis included 39 Australian locations, both within and outside of Queensland, where chickpea is currently grown or has potential for cultivation, and 29 Indian locations where chickpea is grown a major crop (Table1). Some of the Australian locations outside of Queensland were also included to identify homoclimes within Australia as well as to provide a check to test the sensitivity of the method used (e.g. Katherine and Kununurra). Climatic databases of these locations were collected from various sources, including the Department of Natural Resources, the National Ocean and Atmospheric Administration (NOAA), USA, and the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT). Monthly means of maximum and minimum temperatures, and day-length, for the five chickpea growing months (May to September in Australia, and November to March in India) were then calculated from these databases. These means were then subjected to hierarchical complete linkage clustering using Genstat version 6.1. The clustering procedure produces very tight clusters of similar cases, which served the purpose of this study. The clustering output was plotted using ArcView(version 3.3) software and also subjected to further analysis by deriving maximum and minimum temperatures, day length and rainfall means to understand biological implications of the clustering thus obtained.

Results and Discussion

The major climatic factors affecting growth, phenology and productivity of chickpea in different environments are water availability, temperature and daylength,. The present study initially concentrated on identifying homoclimes based on temperature and day length, as temperature and daylength are known to be the major determinants of growth and phenological development. Later homoclime analyses are planned to include variations in soil water availability.

The analysis grouped the Australian locations into four clusters (Table 1, Fig. 1). The analysis effectively separated locations of the three chickpea agro-climatic regions of north, central and peninsular India, which conform closely with the classification of agro-ecological regions for chickpea production in India (Virmani, 2003). The Australian locations falling within the same cluster as other Indian locations can be considered as homoclimes of those Indian locations. In Australia, locations from central Queensland 'homoclimed' with all locations in central India. This central Queensland cluster did not generally include any other location from other states of Australia, which supports the empirical evidence that chickpea adaptation in some of the Queensland locations differs from those of other Australian chickpea production regions. The only notable exception to this was Geraldton, a location in Western Australia, that 'homoclimed' with Central Queensland locations in spite of the fact that it was located on more temperate latitudes. The superior adaptation of the newly released variety 'Moti' (WACPE2012) in central Queensland, developed in Western Australia, supports the hypothesis that some of the germplasm developed in Western Australia could be adapted in central Queensland due to this unexpected homoclime.

All locations from southern Queensland 'homoclimed' with all locations in northern India. In contrast, only a few locations in southern Australia found any homoclime from the Indian locations included in this study. Locations in northern Australia 'homoclimed' with locations in peninsular India owing to the relatively warmer temperatures and shorter daylengths.

There were consistent differences in temperatures in different clusters, with maximum temperatures being greater for the northern Australian and peninsular Indian locations and the lowest for the southern Australian the clusters (Fig. 2). Day length was also greater for the northern Australian and peninsular Indian locations at the beginning of the growing season. Longer days are known to hasten flowering in chickpea (Elis et al., 1994) and therefore chickpea grown in peninsular India has the shortest duration. The cluster with southern Australian locations had the lowest minimum temperatures and also received maximum rainfall during the growing season, which is typical of the Mediterranean type of climate. Minimum temperatures of less than 10^{o}C have been shown to prolong the maturity period by reducing pod set (Saxena, 2003), while maximum temperatures > 30^{o}C reduce pod set and cause hastened maturity (Thomas and Fukai, 1995). Crop duration of chickpea in some of the Australian locations for which data was available was similar to those Indian locations falling within the same cluster (data not presented), which suggesting good matching of crop maturity, a biological trait, within a homoclime cluster.

Table 1. Australian and Indian locations, their latitudes and longitudes, and clusters to which they belong

No	Location[a]	Lat.	Long.	Cluster[b]	No.	Location	Lat.	Long.	Cluster
				Australian locations					
1	Bandigo	-36.4	144.2	4	21	Cecil	-27.4	151.2	3
2	Horsham	-36.4	142.1	4	22	Dalby	-27.1	151.2	3
3	Bridgewat	-36.4	143.6	4	23	Surat	-27.1	149.0	3
4	Shepparton	-36.2	145.2	4	24	Condomine	-26.6	150.1	3
5	Esperance	-33.5	121.5	4	25	Roma	-26.3	148.5	3
6	Swanhill	-35.2	143.3	4	26	Bundaberg	-24.5	152.2	1
7	Walpeup	-35.1	142.0	4	27	Moura	-24.3	149.6	1
8	Portliconln	-34.4	135.6	4	28	Banana	-24.3	150.1	1
9	Gawler	-34.4	138.4	4	29	Biloela	-24.2	150.3	1
10	Mildura	-34.1	142.1	4	30	Orion	-24.1	148.2	1
11	Eyre_peninsula	-33.4	135.5	4	31	Bendee	-23.5	148.2	1
12	Minnepa	-32.5	135.1	3	32	Gindie	-23.4	148.1	1

13	Merredin	-31.3	118.2	3	33	Gogango	-23.3	149.5	1
14	Tamworth	-31.0	150.6	3	34	Emerald	-23.3	148.1	1
15	Geraldton	-28.5	114.4	1	35	Capella	-23.1	148.0	1
16	Thallon	-28.4	148.5	3	36	Clermont	-22.5	147.4	1
17	Goondiwindi	-28.3	150.2	3	37	Dysart	-22.4	148.2	1
18	Warwick	-28.1	152.0	3	38	Kununurra	-15.5	128.4	2
19	St George	-28.0	148.3	3	39	Katherine	-14.3	132.2	2
20	Moonie	-27.4	150.2	3					

Indian locations

1	Coimbtore	11.0	77.0	2	16	Parbhani	19.1	76.1	2
2	Bangalore	13.0	77.4	2	17	Rahuri	19.2	74.4	2
3	Bellary	15.0	76.0	2	18	Aurangabad	19.5	75.2	2
4	Annigeri	15.1	75.0	2	19	Nagpur	21.1	79.1	2
5	Hagari	15.1	77.0	2	20	Indore	22.4	75.5	1
6	Nandyal	15.2	78.2	2	21	Jabalpur	23.1	79.6	1
7	Dharwad	15.3	75.2	2	22	Sagar	23.5	78.5	1

8	Raichur	16.1	77.2	2	23	Kota	25.1	75.5	1
9	Bheemr	16.4	76.5	2	24	Allahabad	25.3	81.5	1
10	Bijapur	16.5	75.4	2	25	Agra	27.1	78.0	1
11	Gulbarga	17.2	76.5	2	26	Delhi	28.4	77.1	3
12	Patancheru	17.4	78.2	2	27	Hisar	29.1	75.5	3
13	Sholapur	17.4	75.5	2	28	Ludhiana	30.6	75.5	3
14	Mohol	17.5	75.0	2	29	Amritsar	31.4	74.6	3
15	Jeur	18.0	75.0	2					

[a] The Australian locations Nos. 16 to 37 are in Queensland state, and rest are in other states. The Indian locations Nos. 1 to 19 are in peninsular India, 26 to 29 in north India and rest are in central India.
[b]Clustering done using maximum and minimum temperatures and day length during chickpea season variables.

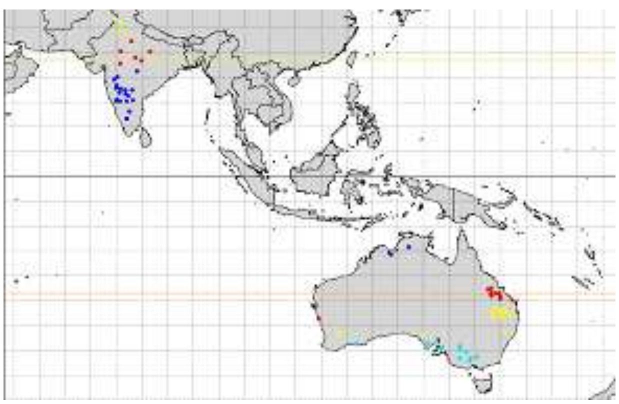

Figure 1. Homoclime locations (represented by the same colour) based on maximum and minimum temperatures, and day-length during the chickpea season in Australia and India

Conclusion

All the locations in central and southern Queensland ‘homoclimed’ with Indian sites, however there was no commonality for southern Australian locations. This observation may have considerable implications for both Queensland and Indian chickpea industries. Firstly, appropriately adapted germplasm from Indian locations could be found for possible testing and adoption into central and southern Queensland regions. Secondly, a variety introduced from India may better meet the quality parameters of Indian consumers and therefore be more readily exportable to that region. Also, these advantages to the Queensland chickpea industry need not be unidirectional, as superior adapted chickpea varieties in central or southern Queensland region may provide growers with new varieties in the respective Indian homoclime. Future research will validate and further refine homoclime matching by using chickpea simulation models. Such models can filter the effect of day length, radiation, temperature, and rainfall etc , and integrate the diurnal and seasonal changes in climate data to account for differences in crop adaptation to different environments/sowings. Limitations of frost and drought stress could also be simulated and assessed.

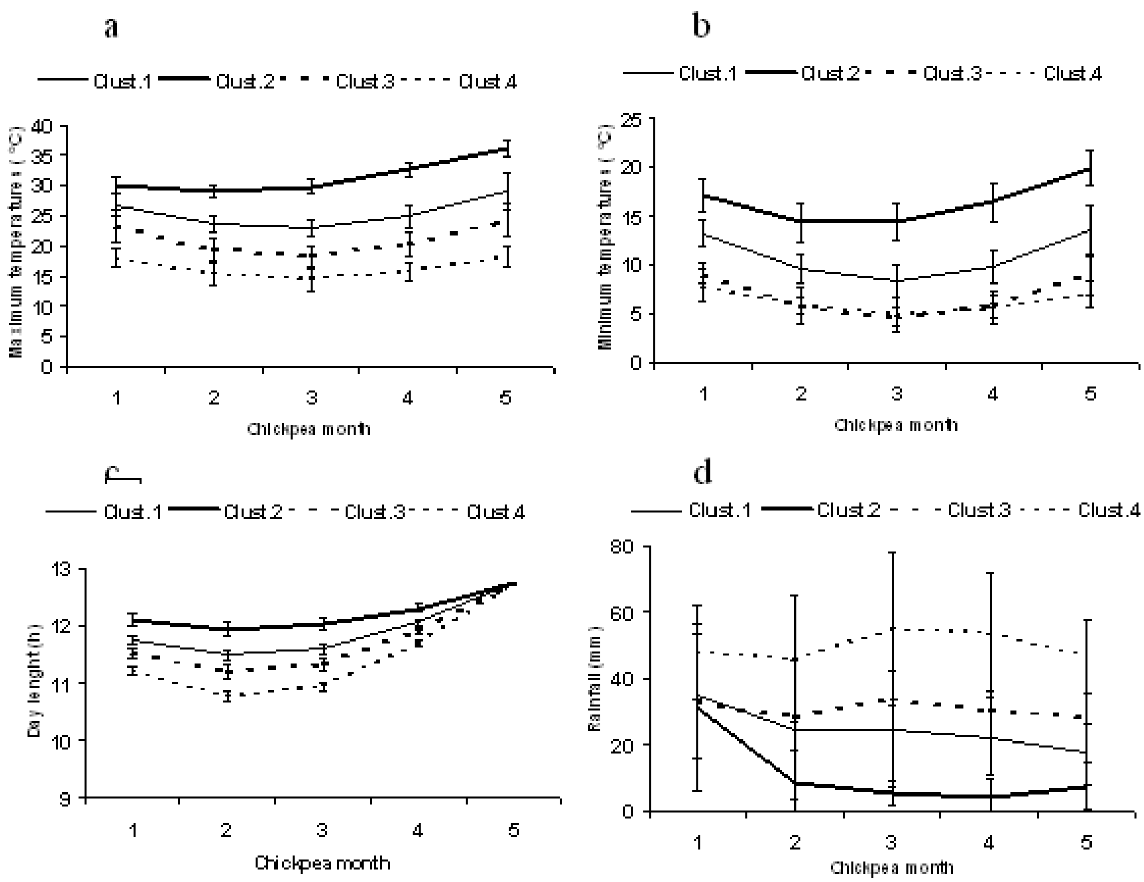

Figure 2. Variation in maximum (a), minimum (b) temperatures, day length (c), and rainfall (d) amonst different clusters of locations over the chickpea growing months. Cluster 1 includes central Queensland and central Indian locations, cluster 2 includes peninsular India and northern Australian locations, cluster 3 includes southern Queensland and north Indian locations and cluster 4 includes the remainder of the southern Australia's more temperate locations. The error bars are standard deviation for variation across locations with in the clusters.

Acknowledgements

Authors wish to acknowledge the financial support received from the Grains Research Development Corporation (GRDC) under project DAQ553.We also acknowledge the support and guidance of Dr N.P. Saxena from ICRISAT and Dr Pooran Gaur also from ICRISAT for supplying climatic data of some Indian locations.

References

Elis R H, Lawn RJ, Summerfield RJ, Qi A, Roberts EH, Chay PM, Brouwer JB, Rose JL, Yeates SJ, Sandover S(1994). Towards the reliable prediction of time to flowering in six annual crops. V. Chickpea (*Cicer arietinum*). Experimental Agriculture 30, 271-282.

Malhotra RS, Pundir RPS, Slinkard, AE (198). Genetic resources of chickpea. In: Saxena, M.C. and Singh, K.B. (eds.) The Chickpea, 67-82. CAB International, Wallingford, UK,

Saxena NP (2003). Management of drought – a holistic approach. In: Saxena, N.P. (ed.) Management of Agricultural Drought – Agronomic and Genetic Options. Oxford & IBH Publishing. New Delhi, pp. 103-122.

Siddique KHM, Sykes, J (1997). Pulse production in Australia past, present and Future. Australian Journal of Experimental Agriculture 37, 101-111.

Thomas, Fukai S (1995). Growth and yield response of barley and chickpea to water stress under three environments in southeast Queensland. I. Light interception, crop growth and grain yield. Australian Journal of Agricultural Research 46, 17-33.

Virmani SM (2003). Research and development strategies to counter drought impacts for sustained chickpea production in the tropics In: Saxena, N.P. (ed.) Management of Agricultural Drought – Agronomic and Genetic Options, 19-24. Oxford & IBH Publishing. New Delhi.