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METEOROLOGICAL FACTORS AND THEIR INFLUENCE ON THE EPIDEMIOLOGY OF THE CASSAVA MITES

by

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Z.M. Nyiira

1. INTRODUCTION

Cassava is estimated to be a staple for over 300 million poeple. It is considered to be one of the world's most important food crop especially in the tropics.

Cassava is essentially an energy source. It is extremely of high potential among the low-income population of the developing world.

Similar to other root and tuber crops and the aroids, cassava has an advantage in that it can be stored in the ground for up to 3 years serving as starvation insurance for the small farmer during which time it is literally unexposed to storage pests. It is now believed that with the increasing world population and increasing economic significance of livestock, cassava will play an increasing role as an energy food and livestock feed.

The future economic significance of cassava is also seen in the context of desertification and the possible expansion of the drought in the Sahelian zone and other tropical areas. Cassava can stand drought. It is a crop on which research should be increased to develop drought-resistant varieties for distribution and cultivation in drought-stricken areas.

Cassava and other tuberous crops whose yield depend on the number and size of the thickened roots, use the aerial photosynthetic parts of the plant as source of carbohydrates for root filling. With greater emphasis on developing cassava to be cultivated on modern scientific methods, attention has been turned to factors of greater influence to its yield.

In this exercise, it is found that the majority and major pests are also responsible for reduced yield of cassava among which are mites belonging to the group Acarina.

Mites affect apices and stems and reduce the leaf area with extended loss of chlorophyll in cassava. The stems and petioles which act as the transport system of carbohydrates to the roots and nutrients to the leaves, are also affected. The plant yield is thus affected.

The development and behaviour of mites and the subsequent survival and infestation and damage of cassava are greatly influenced by a set of meteorological factors.

This paper sets to examine and review meteorological factors and their influence on tetranyohid mites with particular emphasis on the epidemiology of the cassava mites.

In an equiry concerning effects of meteorological aspects as they affect biological agents, it is essential to consider the background of meteorology, biological habitats and the principles and concepts pertaining to interactions between life and the surrounding environment.

1.1 Biological Habitats:

There are three main biological habitats. These are:- Water, land and air space.

1.2 Water:

Water has several unique properties which combine to minimise temperature changes; thus the range of variation is smaller and changes occur more slowly in water than on land or in air. The most important of these properties are:-

1) High specific heat
2) High latent heat of fusion
3) Highest known latent heat of evaporation
4) The greatest density of water is at 4°C, below or above which it lights. This property prevents the acquatic environment from freezing solid.

Penetration of light, concentration of oxygen (O_2) and carbon dioxide (CO_2) are often limited in water restricting photosynthesis activities. Concentration of oxygen in water, is lower than in the air while that of carbon-dioxide, may be present in water in variable amounts for carbon-dioxide is extremely soluble in water. Moderate increases in CO_2 in water seem to speed up photosynthesis and the development of many organisms. However high concentration of CO_2 may be limiting to life, especially animal life, considering that high carbon dioxide concentrations are associated with low oxygen concentration.

The concentration of biogenic salts such as nitrates, phosphates and chlorides seem to be limiting factors to life especially in fresh water biology. However, through osmo-regulation, aquatic life has adapted itself to living with salts in their environment.

1.3 Land:

The terrestrial environment is generally conceded to be the most variable in terms of time and geography. Organisms on land are constantly confronted with the problems of:

1) dehydration
2) extremes of temperature variation
3) geographic barriers limiting free movement of biological material. Terrestrial environment offers solid support for plants and animals built of strong skeletons and specialised locomotory organs.

The soil acts as the substrate and source of highly variable nutrients such as nitrates and phosphates.

Thus, the terrestrial ecology is the most adapted for life because of the existence of association between plants and animals and the provision to plants of enough radiant energy to change it into potential food energy essential for life. All the biological world obtains its potential chemical energy from organic substances produced by plant photosynthesis or micro-organism chemosynthesis which result from radiant energy.

1.4 Air:

Life in the atmosphere is an outflow of biological activity on the land. It is either recorded as a result of involuntary drift, immigration or suspended biological material resulting from man's activity. Plants and animals found in the atmosphere are adapted to atmospheric properties. The major of these atmospheric properties is solar radiation.

a) Solar radiation:

At high altitudes the solar beam is concentrated and contains the short-wavelength ultraviolet which is lethal to life. However, the solar beam is partially depleted in the course of passing through the atmosphere.

Molecules of Oxygen (O_2) absorb some of the photons of radiation and the reactions which follow which involve atomic and molecules oxygen from Ozone (O_3). Ozone gas becomes more concentrated at altitudes ranging rom 25-32 kilometres. It acts as an opaque window absorbing all the solar radiation shorter than 0.3 microns in wavelength to which belongs the lethal short-wave length ultraviolet. In this way life in the atmosphere is safeguarded against ultraviolet rays. Clouds, especially Altostratus overcasts, reflect as much as three quarters of the solar beam back to space. Finally, the radiation beam that reaches the lower atmosphere and the earth is weak and harmless to most living things.

b) Level and range of temperature:

Vertical distribution of temperature is closely linked with biological activity in the air space or atmosphere. Observing that the earth is heated from below, the temperature falls with increased altitude. Low temperatures are known to inhibit breeding in certain biological agents such as birds and insects.

c) Humidity:

The air space contains water in gaseous form referred to as water vapour. Clouds result from the excess water vapour in air after saturation of the atmosphere. Air humidity can thus be considered to be on the higher side. Humidity is considered to be an important determinant in flight and dispersal activity of insects and mites. High humidities have been observed to stimulate longer flights in insects especially in the Desert Locust (Schistocerca gregaria) and in the Red Locust (Nomadacris septemafascicta).

d) Windspeed and direction:

These factors influence rate and direction of migration and dispersal of aerobiological agents and airborne mites and of insects and birds. It also determines the floating distances of fungal spores and airborne acarina in the atmosphere.

There are other properties which can be considered to be of influence to biological activity in the atmosphere. These include: atmospheric pressure, behaviour of gases in the atmosphere, wave cyclone, hail stones, tornadoes, hurricanes, atmospheric electricity and air pollution from man's activities.

2. Cassava mites; their biology and relation to meteorology

2.1 The importance of spider mites as pests of cassava:

Prior to the green cassava mite Mononychellus tanajoa (Bondar) epidemic which swept Uganda during 1972 and subsequent years, there was little concern over mites as pest of cassava. It was, however, known that spider mites infest cassava in South and Central America (Bondar 1938, Rosetto, 1970; Paschoal, 1971), the Caribean (Evans, 1952; Pritchard and Baker, 1955), Asia (Johnston, 1963; Leafmans, 1915) and Africa (Pritchard and Baker, 1955; Rodrigues 1950).

The species of spider mite known to attack cassava then included Tetranychus urticae (Koch) (T. tetarius Linneans) T. bimaculatus Harvey, T. cinnabarinus Boisduval, T. timidius Banks Mononychellus carribeanae (McGregor), M. planki (McGregor), M. chemosetosus (Paschoal), M. bondari (Paschoal) M. Planby (McGregor), M. tanajoa (Bondar) and Oligonychus gossypii (Zacher).

This list has constantly been reviewed. Table 1 indicates the present number of the known species.

Table 1: Acarina reported attacking or recorded on growing cassava (Manihot esculenta Crantz.)

Family, Genus and species	Region where reported
Tetranychidae:	
Eutetranychus orientalis Klein	The Philippines, Thailand
Eutetranychus bauksi McGregor	South America
E. Enodes Baker	Congo (Belgian) = Zaire
Mononychellus bondari Paschaol	Brazil, Colombia
M. Carribeanae (McGregor)	Barbados Nicaragua, Peru, West Indies
M. Mcgregori (Flechtman and Baker)	Colombia
M. tanajoa (Bondar)	Brazaville, Brazil, Burundi, Colombia, Congo, Guyana, Kenya, Paraguay, Rwanda, Sudan, Surinam, Tanzania, Trinidad, Uganda, Zaire, Zanzibar
Oligonychus bigarensis (Hirst)	India
O. coffeae (Nietnar)	Mozambique
O. gossypii (Zacher)	Angola, Nigeria, Siera Leone, Zaire
O. peruvianus (McGregor)	Colombia, Guatemala, Mexico, Peru, U.S.A., Venezuela
Tetranychus amicus Mayer & Rodrigues	Mozambique
T. cinnabarinus Boisduval	Angola, Brazil, India, West Indies
T. kanzawai Kishida	Philippines, Taiwan, Thailand
T. lombardani Baker and Pritchard	Mozambique
T. marianae	Pacific Islands
T. mexicanus	Colombia
T. neocalendonicus Adre'	Kenya, Madagascar, Mauritius, Zaire

Table 1 (Cont.)

Family, Genus and species	Region where reported
(= *T. curcubitae*)	Angola, Bahamas, Egypt, Hawaii, Malawi, Mozambique, Puerto Rico, Swaziland, U.S.A., Venezuela, Zambia
T. sayedi Baker and Pritchard	Zaire
T. truncatus Ehara	Philippines, Taiwan, Thailand
T. tumidius Banka	Mexico, Trinidad
T. urticae Koch	Brazil, Colombia, Peru
T. yustii McGregor	Thailand
Brevipalpidae:	
Brevipalpus phoenicis Geijskes	Brazil, Paraguay

Together the species constitutes the cassava mite complex. It is, however, certain that the most serious damage to cassava is inflicted by Mononychellus tanajoa commonly known as the green cassava mite and possibly by M. carribeanae, M. planki and T. cinnabarinus, although Rodriguez (1977) considers T. urticae as the most damaging. Generally, the seriousness of either of them or their combination is influenced by environmental factors particularly the state of the synoptic meteorology of much of the area concerned.

2.2 Eco-biology and behaviour of cassava mites: -

Airborne dispersal of spider mite is of particular interest both to the meteorologist, the aerobiologist and the agriculturist alike. Atmosphere, similar to water and land, is a complex habitat in which there is a complex interaction between meteorological factors and airborne particulates. Airborne particulate matter consists of inorganic material such as gases, dusts, radio nuclides and particles and organic biological forms which include viruses, bacteria, protozoa, fungus fragments and spores, algae moss, lichens and fern spores, minute plant seeds, plant fragments and pollen, insects and microbiological agents.

Species of spider mites associated with cassava have been recorded airborne through air currents.

Although particulate objects such as mites can be airborne for a long time through long distances, the modes by which they are air-lifted are varied. Some species form ballooning threads by which they lower themselves from a leaf and are picked up by air currents and carried for some distance. Among these is M. tanajoa (Nyiira 1975). Others such as T. cinnabarinus lack ballooning threads (Boyle 1957). In the absence of such threads, stronger winds are needed to make them airborne after which light air-currents can keep them in space as suspended particulates.

The potential and practical importance of meteorological factors in relation to the biology, ecology and dispersal of spider mites, particularly green cassava mites, is now recognized (Nyiira, 1975). It is generally accepted that areas and seasons of outbreaks of the green cassava mites are areas and seasons of dry spells. Dry weather, relatively, favours increased density of the green cassava mites and production of their eggs. Their population and egg production subsides during and after rain.

Evidence of a similar role of wind in dispersal of mites has also been reported by Ewing (1914) for T. urticae although Coghill and Ingram (1962) found little evidence of wind dispersal for the same mite species in England.

2.3 Relevant aspects of the biology of spider mite pests of cassava:-

It is essential for the meteorologist to be acquainted with the relevant aspects of the biology of the cassava mite species in order to consider the inter-relationship between meteorological factors and the life history and behaviour of the mites. The conspicuous distinct stages of mites successively from egg to protonymphs, to deutonymphs and finally to adults, are individually affected differnently by different meteorological factors. Such influence determines the fate and success as pests of the mites in a particular area and season.

2.3.1 The green cassava mite, Mononychellus tanajoa (Bondar)

The adult green cassava mite is very tiny with an average body length of 350μ. It lays its eggs on undersurface of the cassava leaf. The egg is about half the size of the adult mite.

The number of eggs laid per female varies with temperature from 3 eggs per female per day at room temperature (average 22.9°C) to about 4 eggs laid when the relative humidity is around 60% at room temperature.

The egg, when first deposited, is spherical and transparent. As incubation progresses it turns pale-straw first before hatching.

The duration of the egg stage varies with temperature and relative humidity. During a study at Kawanda Research Station (Uganda), for example, the egg stage duration ranged from 5 days at room temperature to 4 days at 32°C. Shorter incubation period was recorded at low relative humidity levels.

2.3.2 The red spider mite, T. telarius Lineaus (= T. urticae)

Adult females of this mite are known to diapause during cold temperature (van de Bund and Helle 1960). According to Bodarenko (1950, 1958) photoperiod is of great importance in the inception of diapause in addition to cold temperature. However, Nuber (1961) submits that diapause is dependent on temperature and food and that light exerts little influence provided the diapausing mites have been exposed to sufficiently low temperatures.

As for dispersal, Hussey and Parr (1963) postulate that T. telarius (= T. urticae) spreads, among other methods, by dropping off from heavily infested plants and migrating over the soil surface in accordance with the plane of polarised light. T. urticae has, however, not been observed to suspend itself on silken threads as do M. tanajoa.

2.3.3 T. cinnabarinus Boisduval

The biology of T. cinnabarinus closely resembles that of T. telarius (= T. urticae). However, unlike the latter, T. cinnabaruns does not diapause, at least in the green house, particularly in Netherlands (van de Bund and Helle, 1960). This species too, is considered to be vulnerable to spread by air-currents although, according to Boyle (1957), the species does not produce ballooning threads.

2.3.4 Other Tetranychus, Mononychellus and Oligonychus species of spider mite pests of cassava:-

Little is known of their biology. They are normally abundant during dry weather conditions. They, generally, inhabit lower surfaces of their host plants. Some of them live under cover of thick webbing where they are protected against inclement weather.

According to van de Vrie et al. (1972), most of the tetranychids inhabiting cold regions, commonly pass the winter in a dormant diapausing stage. Many authors believe that the main factors inducing diapause even in the species whose biology is little studied, are temperature, photoperiod and nutrition. Of the three, temperature and photoperiod are considered predominant while nutrition is considered to have a minor role.

2.3.5 Brevipalpus phoenicis Geijeskes (Tenupalpidae):-

B. phoenicis has only been described by Pschoal (1971) as a pest of cassava. If it is, it is extremely of low importance. Its distribution is, however, wide as a pest of citrus.

3. The response behaviour of cassava mites:-

Observations on T. urticae under low versus high relative humidity by Mori and Chant (1966) showed that under laboratory conditions at 23.3°C this species of mite reacts sharply to avoid high humidity. It almost stops moving after being exposed to high humidity for 4 hours and over; but when exposed to lower humidity it recovers and continues moving.

The influence of air humidity on the hygrotaxis and hygrokinesis of spider mites has also been studied by Winston (1963a, b). His results agree with those of Mori and Chant.

Evidence from other workers, particularly Jeppson (1952), show that other species of tetranychid mites which, though not pests of cassava belong to the same family as the cassava mites, thrive well in cool but humid conditions. They give the example of Eotetranychus sexmaculatus in the coastal areas of California. Generally, however, even such species have adopted themselves more to the dry, semihumid area (Lewis and Schilling 1950, Munger 1963).

3.1 The role of wind in aerial dispersal of cassava mites:-

Extensive series of observations on the dispersal of M. tanajon, recorded regularly at heights up to 30 metres above the ground, showed marked association between mass transportation by air currents of the green cassava mites and temperature gradients and air movement speeds. Thus atmospheric terbulence, that is, air-movement in all directions, lateral as well as vertical, is capable of dispersing the mites in all directions because of the positive temperature gradient which favours the rise of hot air and mites alike, by convection currents. The mites rising by the vertical terbulent can thus be blown in lateral directions to long distances causing long distribution of the pest.

Alternatively, since it is an accepted principle that any air-borne material which is without any systematic horizontal motion of its own relative to the air, is displaced down-wind. The mites rising by the vertical terbulents created by the convection currents will float down wind for distances towards and into areas of low level convergence. The distances covered by this method of dispersal will depend on the wind velocity and density of the individual mites.

More circumstancial evidence (based on case studies) have confirmed the dispersal of cassava mites resulting from the air terbulents and down wind displacement. Such evidence account for pocket infestation of cassava by the green cassava mites (Nyiira, 1975). The evidence available on optimum air temperatures favouring aerial dispersal of M. tanajos indicated that temperatures between 24°C in slight air currents, favours migration or dispersal of the green cassava mite. There have been records when dispersive tendencies have been observed at lower or higher temperatures than those reported. A preliminary quantitative examination of the temperature/dispersal relations of the green cassava mite was carried out at Kawanda Research Station in Uganda in April of 1973. The results are summarized in Table 2.

It will however, be noted that temperature response of mites interacts with time of day. This evidence suggests that while temperature is a critical determinant of aerobiological activity in green cassava mites, it is possible that other factors such as air humidity prevalent at the different hours of the day and photoperiod will determine the reaction to temperature of the mites. Nevertheless, the evidence revealed by the data in Table 2 and Table 3 reveal a reasonably consistent pattern of more activity by green cassava mites in displaying dispersive tendencies at temperatures between 24°C and 29°C.

Table 2: Green cassava mites displaying dispersive tendencies at various temperatures and time of day at Kawanda Research Station:-

Temperature	Hours after day and numbers of mites					
	9 a.m.	11 a.m.	1 p.m.	3 p.m.	5 p.m.	Totals
20	64	-	-	-		
21	51	-	-	-		
22	119	-	-	-		
23	7	-	-	-		
24	-	18			20	
25	-	152	-	1	1	
26	-	95	22	-	18	
27	-	-	103	-	16	
28	-	-	53	47	6	
29	-	16	-	75	58	
30	-	-	18	6	-	
31	-	-	-	-	46	
32	-	-	4	-	-	

Table 3: Total mites suspended at various temperatures (^{o}C) in the laboratory and outside in the field.

Mean temperature	Mites Suspended		
	Laboratory	Field	Total
22	-	28	28
24	85	11	96
26	73	-	73
28	58	73	131
30	19	-	19
32	-	4	4

3.2 Air Temperature:

Theoretically, temperature equilibrium in mites, is attained by heat exchange between the air temperature and the mites. Thus, mites will gain heat from the air whenever their body temperature is below the air temperature and will lose heat to the air whenever their body temperature is above that of the air. As for the locusts (Rainey, 1974) heat exchange with the air in mites is through respiratory ventilation and by convection from the external cuticles.

The thermal effect of air temperatures on cassava mites is unknown. However, Wharton and Cross (1957) observed that the amount of feeding and injury of mites (generally) are related to the water balance in mites. At the same time, higher air temperatures, not only dislocate the water balance in mites but tends to desiccate the organisms, particularly in the egg stages by dehydrating them. It can only be postulated that sustained higher air temperature is likely to affect the population of the cassava mites. Such a phenomenon, equally, may be responsible for more injury to cassava.

The feeding and injury to cassava of green cassava mites is considered to be enhanced by high air temperatures. On the other hand, high air temperatures are likely to be responsible for possible desiccation, reduced egg viability and possible mortality. It is probably logical to deduce that meteorology can determine confidence limits of ambient air temperatures favouring severe injury and temperature and confidence limits within which reduced population and mortality can be expected. Singly or in combination with relative humidity, air temperature has direct effect on the amount of feeding and damage by mites and also on the water balance in them. Cassava mites feed on moisture-laden plant tissues and thus make up for loss of water to the atmosphere. This is why more severe damage is inflicted in drier areas or during dry weather.

In dry air, the egg stage is vulnerable to rapid desiccation. Nyiira (unpublished data) noted that <u>M. tanajoa</u> eggs on cassava in the laboratory dehydrated and failed to hatch at combinations of 5% R.H. and 16^{o} -25^{o}C but hatched after 3 - 4 days at a mean R.H. of 10% in temperature ranges of 16^{o} - 25^{o}C.

3.2.1 Biology and ambient temperatures:

The foregoing discussion has not considered temperature relationships with regard to development stages. Mean incubation periods for <u>M. tanajoa</u> is influenced by temperature conditions. For instance, in Uganda, the incubation period recorded at 22.5°C, 25°C and at 28°C was around 5 days compared to 4 days at 32°C (Nyiira, 1975). During the same study there was an indication that eggs would fail to hatch if continuously incubated at temperature above 35°C.

A similar conclusion has been reached in respect of fecundity in M. tanajoa. Once again Nyiira (1975) found that, during 10 days after the preoviposition period, females of M. tanajoa laid more eggs per female at temperatures between 30 - 32°C while the fecundity rate was observed to be low at temperatures below 22°C.

Development period of the various stages of the green cassava mite is equally affected by temperature. Longer development periods have been recorded at temperatures below 25°C and above 32°C.

Table 4: The effect of temperature* on fecundity rate, incubation rate, incubation and on nymphal duration of *Mononychellus tanajoa*.

	Temperatures (°C)			
	22.9	25	28	32
Mean incubation period (days)	5.1	5	5	5
Mean duration (days) of hymphal period.	9.4	8.7	8.4	8.6
Fecundity rate (eggs/♀/day)	3.3	3.2	3.2	3.8

*under fluctuating RH ranging between 50% - 85%

3.3 Relative humidity effects on M. tanajoa

The magnitude and nature of response of M. tanajoa to variations in the relative humidity has again, not been extensively studied. The little information known has also been studied in isolation disregarding other factors, such as temperature that go hand in hand with changes in the relative humidity.

Some observations have been reported (Arruda unpublished) on the effect of changes of relative humidity on M. tanajoa. He observed that very high relative humidities are not favourable for population increases in the green cassava mite.

Recent observations by the author agree with the observations by Arruda.

Oviposition in M. tanajoa is influenced by relative humidity. For instance, maximum oviposition at temperatures around 23°C has been recorded at 60% relative humidity while the same temperature, the lowest oviposition rate is recorded at 30% relative humidity. The average oviposition life is also longer at relative humidities between 50 - 60%.

Table 5: Oviposition pattern of M. tanajoa more different relative humidities at temperatures of 15.8°C - 30.5°C.

	Percent relative humidity levels								
	20	30	40	50	60	70	80	90	100
Total number of eggs laid/ female for the 1st 10 days after preoviposition	16	21	46	67	69	37	25	25	22
Mean number of eggs laid/ female/day	1.5	1.5	2.9	3.7	4.6	3.1	2.3	1.5	2.0
Average oviposition life span of female (days)	25	25	27	31	30	33	27	20	17

Table 6: Duration of instars of the green cassava mite M. tanajoa under different relation humidity levels

	Duration (days) Relative humidity levels (%)								
	20	30	40	50	60	70	80	90	100
Larva	6	6	5	4	4	4	4	6	5
Protonymph	3	3	3	3	3	3	4	4	4
Dentonymphy	2	2	2	2	2	2	3	3	2
Total duration	11	11	10	9	9	9	11	13	12

3.4 Effect of rain on population of cassava mites:

During rainy periods, cassava mites suffer a reduction in population (Kramer 1956). This reduction is believed to be due to the mites and their stages being washed off from foliage (Prost, 1919; Hamilton, 1926; Franklin, 1929). Kramer (1956) while working with Bryobia rubrioculus (= B. praetiosa) found that exposing this species to wet conditions for 4-16 hours caused 30 - 95% mortality. He, however, noted that the quescent stages were not affected. Heavy rains might be expected to cause mortality, particularly in species of mites that inhabit the upper surfaces of leaves and are not protected by webbings.

Almost all those cassava mites, particularly M. tanajoa, T. cinnabarinus, and t. urticae inhabit the undersurface of cassava leaves. They are not exposed to direct rain drops. They are found huddled along the midribs and veins, especially when in low numbers. However, the results by Nyiira (1975) show that rain has negative effect on their numbers.

3.5 Photoperiodicity:

Little is known about the effect of photoperiodicity on the biology and behaviour of the cassava mites. It is, however, known that some spider mites hatch more successfully when kept continuously in darkness. Hueck (1951, 1953) on the other hand found that development of winter eggs of Pononychus ulmi, a tetranychid, kept in darkness at 25^{o}C and 75%, R.H. was arrested at about the moment of hatching.

It therefore appears that light periods have varying effects on the development of eggs and possibly of active stages of mites and may provide stimulus to the fully grown embryo to break the egg shell.

In M. tanajoa hyperactivity among active stages is noticed during sunlight. Effect of presence or absence of light on their dispersal is however, not known.

4. Season effects on population dynamics:

Weather has direct influence on the innate capacity for reproduction and survival of mites. It also has indirect influence on the dispersal of mites and other aspects of their behaviour such as their abundance, distribution and degree of infestation and damage.

It is clear that while climate may be an important factor in the distribution of mites, weather influences their seasonal and local abundance.

Seasonal distribution, severity and damage of cassava leaves by mites is associated with the rainfall pattern and also with the regions of the world where cassava is grown. To this extent climatographs are useful tools in forecasting these functions and predicting outbreaks. Climatographs aid the analysis of the inter-relationships between weather components and the population dynamics of the mites.

Seasonal changes affect seasonal variation in the population of adults and immature stages of mites. The effect differs from variety to variety and from one location to another and from season to season. Certain varieties experience the seasonal effects influenced by natural seasonal changes than by edaphic factors and immigration.

A direct comparison of the figures computed from trials carried out at Kawanda Research Station in Uganda on local varieties of cassava for both monthly and weekly variation in population of eggs, nymphs and adult mites showed that the deviations from the expected mean of typical seasonals for the adult mites ranged between 25% on one variety to +8.5% on the other.

These deviations were not statistically significant when tested using the Chi-squared test, implying that the variations due to possible edaphic factors were non-significant and that the factors affecting population variation were mainly seasonal.

4.1 Relationship between mite population and weather:

This aspect was investigated using M. tanajoa because hitherto, it is only this species of spider mite that has caused concern as a pest of cassava.

Visually, populations of M. tanajoa increase rapidly during the dry weather but subside during the wet rainy season. This observation was repeated by Nondar (1938) and by Fletchman and Pereira (personal communication) in Brazil. Further, the long term seasonal population variation has been observed to follow the 5 year cyclical trend and appears to be greatly influenced by natural control factors which in turn are also influenced by weather and climate.

Results of an investigation (Table 7) carried out in Uganda during August - December, 1972 indicated that the correlation between weather components and total number of mites per leaf or their eggs recorded during the same period was low and non-significant, except in the case of monthly rainfall. The effect of individual weather components on mites or their eggs was, however, positive. Perhaps the influence of weather on mite population is a result of combinations or interactions of more than one component.

Critical areas of destructive damage and potential areas of outbreak which represent weather components which favoured the outbreak and the defoliation of cassava leaves are shown in Appendix I.

During 1972 in Uganda, the two months critical period of destructive damage occurred when the weather component combinations were in the ranges of 80.3 to 117.0 mm. of total monthly rainfall, 21.6 - 22.5°C and 76.0 - 77.0% relative humidity. In 1973 the two monthly critical periods of destructive damage occurred when the combinations of weather components were in the ranges of 75 - 215 mm. of total monthly rainfall when the temperatures were 20.9 - 22.2°C and 68.9 - 84.0% relative humidity.

The months in which heavy mite infestations were recorded were not necessarily the less wet ones. However, in both cases, severe damage and heavy mite populations were experienced one or two months following a dry spell of less rainfall and temperatures and relative humidities falling within the preferred range indicated above. These results indicate that there is a variation from one season to another in the weather conditions favouring outbreaks and two severity of damage by mites on cassava. And that the outbreaks and two severity of damage are also dependent on other factors than weather but together influence the damage to cassava by mites.

Table 7: Relationship between mites per leaf and weather components during August to December 1972 at Kawanda Research Station.

		Rainfall	Relative Humidity	Temperature
(a) Adult mites				
	r values	0.41	0.11	0.10
	p level	NS	NS	NS
	number of observations	20	20	20
(b) Mite Eggs				
	r value	0.44	0.16	0.11
	p level	5%	NS	NS
	number of observations	20	20	20

5. Effect of weather on biological control agents of cassava mites:

Natural control factors regulate the population of many living things. Equally the biological control agents of cassava mites are affected by natural factors either directly or indirectly.

The most active biological control agents of cassava mites are predatory mites in the family of Phytoseidae and beetles in the families of Coccinillidae and Stephylinidae. These predators are host density dependent and self regulating.

The effect of weather on them is chiefly indirect through its effect on the survival and distribution of the host mites.

However, there is likely to be direct effect of meteorological factors on the development and survival of the predatory species regulating the population of cassava mites.

The direct relationship between weather components and biological control agents of the green cassava mite, M. tanajoa was indicated by the very low and non-significance of the correlation coefficient (Table 8).

Table 3: Relationship between weather components and biological control agents of the green cassava mite *M. tanajoa* in Uganda

		r value	probability level	number of observation
Rainfall	(1)[a]	+0.03	NS[b]	11
	(2)	+0.02	NS	11
Relative Humidity	(1)	+0.08	NS	11
	(2)	+0.64	5%	11
Temperature	(1)	+0.32	NS	11
	(2)	+0.60	5%	11

a/ (1) and (2) are locations 1 and 2 at which observations were taken.

b/ NS = correlation coefficient not statistically significant at 5% level of probability.

6. Conclusion:

Meteorological research has a great role to play in agricultural development bearing in mind that climate is changing although the form of change is a controversial issue.

The variability in climate implying changes in meteorological factors will certainly affect crop production directly or indirectly. Subsequently human population will be affected.

Pests of crops as factors which reduce crop yield have to be seen in this context. Meteorological factors influence crop production and offer food for these pests. On the other hand these factors affect the innate capacity for reproduction and survival of the crop pests among which cassava mites belong. If this effect is negative the population of these pests will decrease.

Cassava is increasingly gaining importance on the world scene. It is essential to focus attention to possible factors which affect its yield.

It is during this exercise that meteorological factors influencing the epidemiology of the cassava mites, one of the factors responsible for reduction in yield, should be examined.

The following conclusions should be of particular interest to persons interested in this exercise.

a) an understanding of the relationship between meteorological factors and the biology and ecology of cassava mites can be of great benefit to the strategy for their control.

b) an effective forecasting service to aid the control of cassava mites can be worked out based on the knowledge such as:

   (i) wind direction and its influence on the dispersal and distribution of mites.

   (ii) influence of dry spell on infestation and severity of damage by mites

   (iii) Rain and its influence on the biology and survival of mites

   (iv) climatographs and hythergraphs showing areas of destructive damage and potential outbreak areas.

c) Meteorological factors detrimental to cassava mites can equally be detrimental to cassava yield. However, the actual biological processes in which such a phenomenon can apply need characterisation.

d) Mites affect the yield of cassava by interfering with photosynthetic activity of the plant which aid filling up roots and by affecting the transport system in the cassava plant. The infestation by mites of the cassava crop after filling up may not be of economic significance.

Finally it should be noted that the effect of meteorological components on the epidemiology of cassava mites can be positive or negative. The influence differs according to the effect of individual factors or their combination.