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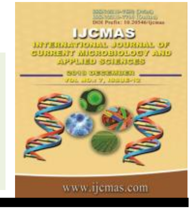

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Climate Change Effects and Quality Makhana (*Euryale ferox* Salisb.) Production under Wetland Ecosystem of North Bihar

B.R. Jana, Anuradha Srivastava* and Md. Idris

ICAR-RCER, Research Centre for Makhana, Basudeopur, Darbhanga, Bihar-846005
**ICAR-RCER, Research Centre Ranchi, Namkum, Ranchi, Jharkhand -834010*

**Corresponding author*

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A B S T R A C T

A field trial was conducted to study the climate change effects on quality makhana production at ICAR-RCER, Research Centre on Makhana during 2016-2017. The objectives of the study were developing new makhana production strategies to secure sustainable production under climate change or various weather conditions. High temperature and reduced humidity resulted in production of rather smaller nuts and leaves. The results revealed that makhana was a photo insensitive crop and its growth and development were markedly changed with the change of climates. Fruit number, seed numbers/fruits and yield were gradually increased from February to till September. Winter climate restricted commercial production of makhana for October transplanted crop. However, November and December planted makhana produced yield similar to January crop after recovering from unfavourable weather of winter. The maximum numbers of fruit (15.33) and yield (62.0Q/ha) were observed in September planted crop. The gestation period of this crop was minimum (110 days) in February planted crop as compared to October (152 days). Winter makhana, which was planted in July showed highest nut quality in terms of protein (11.35 %) content. Plant grown in extreme winter and summer showed decreased in protein content. As far as pest infestation was concerned, the aphid (*Rhopalosiphum nymphaeae*) was found infesting makhana crop at nursery stage in winter. However, no economic damage was observed. During this study, the maximum temperature was 43^{0} C in May (2016) and the minimum temperature was 5^{0}C in January (2017). Hence, high and low temperature resulted in reduction in growth parameters (nut and leaf), while moderate temperature enhances protein production and yield.

Introduction

The plant makhana or fox nut (*Euryale ferox* Salisb.) belongs to the family Nymphaeaceae, have commercial importance due to its seeds which contain unique amino acid composition. It is an aquatic plant grows in stagnant water of lakes and lowland and widely found in Korea, Japan and Russia, New Zealand besides India and Eastern Asia. In China, it has been cultivated in the Hainan and Taiwan islands for 3 - 4 millennia and widely used in Chinese medicine (Bensky, 1993). Its distribution includes the islands of Taiwan (Formosa) and Kyusyu, Shikoku and Honshu in Japan (Okada, 1935). The distribution of this species is now limited to the tropical and subtropical regions of south-east and East Asia. It has been adapted to the tropical climate of India and is found in natural, wild forms in various parts of north-east India (Manipur Assam, Meghalya, and Orissa) and scattered pockets of central and northern India (e.g. Vadodhara. Gorakhpur and Alwar) (Kak, 1985; Shankar *et al.,* 2010). Fox nut plant is stem less having large round leaves and produces bright purple flowers. Being a thorny plant, it needs less water its growth but more for floating of the leaves and flowers (Jana, 2017). In Bihar, particularly in Mithila region is well known for Makhana cultivation under wetland ecosystem since several years ago. Swamp and marshy areas having stagnant water (Kumar *et al.*, 2011) is ideal for cultivation and it has become the pride of poor farmer to provide complete food and nutritional security to the people of this region. With the burgeoning population and urbanization cultivable ponds and field are decreasing day by day. It is also good for sugar patient and developing child as it contains the maximum calcium and other nutrients. The seeds of fox nut are used in ayurvedic preparations (Jha *et al.,* 1991a). It strengthens the heart and is very useful in anaemia (Das *et al.,* 2006). It is also an important ingredient which is used to strengthen spleen and kidneys. It contains less sodium and maximum potassium which reduces blood pressure. It is effective against neuralgia, incontinence, chronic diarrhoea and arthritis (Jha *et al.,* 1991b). It is nutritious and easily digested (Singh and Arora 1978). Its medicinal properties lying on treating circulatory disorders and also as a cardiac stimulant is praise worthy. In pond system of cultivation, the production was very low (1.0-1.2 t/ha). In Bihar, makhana has been cultivated on 11,802 ha that accounted for total yield of 3,37,59.1 T (JIT Report, 2014). Since 1990 Besides being an wonderful aquatic non cereal food crop the area of cultivation is dwindling (In 1990 area was 90,000 ha) due to high temperature, reduced relative humidity and limited water resources which are the major factors resulted in reduction in yield. As the area of water resources are shrinking sustainable management of biotic resources in the wet lands of North Bihar has great important for livelihood security to the rural poor (Jha, 2002). Hatfield *et al.,* (2011), stated that pollination is one of the most sensitive phonological stages to temperature extremes and greatly affect crop production in all crop species and during plant growth stages. The expected changes in temperature over the next 30−50 years are predicted to be in the range of 2−3 °C, Intergovernmental Panel Climate Change (IPCC) (2007). Both cooler and warm temperature affects the protein synthesis and yield. Below 20°C, loss of membrane fluidity might explain the inactivation of membrane-bound processes such as photosynthesis and ion transport and thereby protein synthesis (Graham and Patterson (1982). While studying on protein synthesis in Pear, Ferguson *et al.,* (1994) stated that heat-shock protein (hsp) synthesis was greater at 39^0C than at temperatures above 40^0C. Both cellular uptake of radiolabeled methionine and total protein synthesis were progressively lower as the temperature was increased (45^0C).

To augment the production and maintenance of nut quality under climate change scenario is itself a big challenge to the researchers. Hence, in present study, makhana were grown in twelve different months to assess the actual requirement of crop for maximum production as well as growth of crop and nut quality affected by seasons. The 10 years growth data are also collated to find out the differences in growth parameters.

Materials and Methods

The present study was conducted at ICAR-RCER, Research Centre for Makhana during

2016-17. It is located in the Adhwara-Kamla flood plain (lat 26 0 10' N: long, 85 0 87'). Makhana thrives best in weather having air temperature 20-25^{0}C relative humidity 50-90 % and annual rainfall 100-250 cm (Mandal *et al.*, 2010). So assured irrigation or water for maintenance of makhana plant growth and maturity is essential. Cultivar for experiment was Swarna Baidehi, first ever variety released from the Research Centre of Makhana. Planting date was first week of every month and 30 cm constant water was provided under field condition for proper growth and development. Growth data were taken by standard methods. Data were analyzed by following RBD with 3 replications. Protein was measured by Lowry method and carbohydrates were determined by the Anthrone method (Ranganna, 1997, Thimmaiah, 1999). Dried samples (1g) were digested with diacid mixture (HNO3: HClO4: 9:4). After digestion and extraction of samples, total P was determined with the vanodo-molybdophosphoric acid yellow-colour method (Jackson, 1973) and total K was determined with the flame photometric method (Jackson, 1973). Water-soluble Ca and Mg were determined by the versanate method (Hesse, 1971). Water-soluble Fe was measured with an atomic absorption spectrophotometer (Analyst 100, Perkin Elmer, and Norwalk, CT, USA).

Results and Discussion

Morphological and bio-chemical effect

A close perusal of the table 1 revealed that due to climate change in respect of raising temperature, decreasing relative humidity and rainfall over the decades (2007-2016) nut size of makhana were relatively smaller as well as kernel % was reduced (63.15%-61.74 %). Similarly, the leaf size was significantly decreased (110.48 -106.57) due to high temperature and reduced humidity from decade of study. Data of the table 3 enable us to explain not only leaf sizes but also leaf number was also affected by the high temperature. Apart from nut and leaves the number of floral buds were also decreases from (16.34- 14.62). Makhana is generally grown all over India during June-September in ponds and lowland traditionally. From study of CSIR (1952) to present study (2016) the protein % was increased from 9.7 to 11.16 %. But in the both extreme temperature high and low protein synthesis declines in seasonal study 2016-17 (Fig. 2). Moderately Low temperature, the protein synthesis was the maximum which was reflected in July crop harvested in November (11.35%). This finding was corroborated by the finding of CSIR (1952) and Shankar *et al.*, (2010) (Table 2). The similar finding was observed by Graham and Patterson (1982) and Ferguson *et al.*, (1994.) Both high temperatures in summer due to severe weed infestation in March -April leaves were in congested space which affects subsequent growth along with high temperature of the water and environment. Summer atmosphere also restricted inform of reduction in floral bud number, leave sizes and petiole length of flower and leaves. The yield of the makhana crop was gradually increased from February to September (16.32 Q/ha to 62.0 Q/ha). It has been found that October planted makhana plant survived during winter but its growth and development was too poor to yield the minimum (7.67 Q/ha) by limiting fruit set per cent (28.24%). As the August and September planted makhana gave almost double production protein content of the nut decreases little bit (10.92 %) (Fig. 1–3).

Yield

Data pertaining to table 3 in respect to yield character, the maximum yield of 62.0 Q/ha was observed in case of September, planted Makhana. By utilizing the retrieved flood water or late monsoon September plantation is feasible to harness the maximum production benefit during winter under North Bihar Condition. August transplanted makhana is the second best performer with regard to yield (40.27Q/ha), which may practically be fitted to the farmer of North Bihar without taking risk for nursery raising during normal monsoon (3rd week of June) season. Kumar *et al.*, (2011) reported that yield potential of some superior line at field condition was 2.6-3.0T/ha. The biomass production of the crops were the highest in September planted crop both in terms of fresh weight (33.47 kg/plant) and dry weight (4.53 kg/plant) which incorporate more nutrient to the soil after decomposition. The results were in accordance with the findings of Kumari *et al.*, (2011).

Pollination, fruit set and crop period

Makhana is predominantly self pollinated crop yet its pollination and fruit set was affected by high temperature and low humidity in different growing seasons i.e. September planted makhana had the maximum fruit set (86.22%). This result was confirmed by Hatfield *et al.*, (2011). Fruit contains 180-210 ovules which later developed in to nuts. The maximum seed per fruit was observed 163.25 (Table 4) and its pollination period was mid October for September planted makhana. The gestation period varies from 110 days in February to 152 days in October transplanted crop. Kumar *et al.*, (2011) also reported that makhana is 4.0 months crop (120 days).

Table.1 Climate change and its impact on leaves and nuts over decades (2007-2016)

Years	Leave Diameter(cm)	Nut weight (g)	Floral Bud	Kernel (%)
2007	110.48	1.22	16.34	63.15
2016	106.57	1.13	14.62	61.74
Fisher LSD $P \geq 0.5$	2.64	NS	1.15	1.21

Table.2 Biochemical changes of kernel powder of makhana 2016

Constituents	1952**	2009*	2016
Moisture %	12.8	10.71	11.82
Carbohydrate%	76.9	70.77	75.04
% Protein	9.7	11.02	11.16
Fat%	N/A*	0.41	0.51
Phosphorus %	N/A*	0.08	0.028
Sulpher %	N/A*	0.024	0.042
Calcium %	N/A*	0.037	0.027
Magnesium %	N/A*	0.01	0.006
Potassium %	N/A*	0.042	0.037
Iron %	1.4	0.004	0.006
Ash%	0.4	0.418	0.62
Total	……	**93.525**	**99.296**

*Shankar (2010) and Kumar *et al.*, (2011).

** CSIR (1952)

Table.3 Morphological characters of makhana as affected by different growing seasons (2016-2017)

Treatments	Leaf diameter (cm)	Leaf number	Petiole Length (m)	Fruit petiole length (cm)	Fruit weight(g)	Number of fruits/plant	Number of seeds/fruit	Yield (Q/ha)
FEB	110.33	8.44	1.18	38.77	200.23	7.23	78.34	16.32
MARCH	116.66	8.55	1.26	40.66	205.67	8.12	82.66	18.36
APRIL	119.17	8.75	1.29	41.66	209.08	8.22	82.99	19.25
MAY	122.34	9.92	1.32	43.26	211.33	8.88	88.52	20.92
JUNE	125.83	10.44	1.37	44.88	216.88	9.72	118.76	25.66
JULY	125.33	12.55	1.45	45.25	240.66	10.22	123.35	38.25
AUG	132.66	14.66	1.58	45.66	275.78	12.45	152.64	40.27
SEPT	137.82	15.03	1.62	47.99	324.33	15.33	163.25	62.00
OCT	101.66	12.04	1.34	28.61	155.73	6.92	34.67	7.67
NOV	104.17	10.25	1.36	26.29	187.38	6.62	72.88	10.33
DEC	105.33	10.67	1.40	27.40	190.78	7.53	77.67	14.33
JAN	108.66	10.92	1.44	35.33	196.27	6.88	78.25	17.46
CD at 5%	**6.49**	**4.53**	**NS**	**NS**	**14.32**	**1.27**	**12.34**	**10.73**

Table.4 Morpho-phenological characters as affected by different growing periods during 2016-17

Treatments	Fruit set (%)	Seed Number/Fruit	Seed Weight /(g)	Pollination Period	Gestation period(days)
FEB	45.80	78.34	0.93	Mid March	110.0
MARCH	48.05	82.66	0.97	Mid April	120.0
APRIL	47.77	82.99	0.98	1st Week of May	130.0
MAY	52.62	88.52	1.00	1stWeek of June	132.0
JUNE	66.21	118.76	1.05	1st Week of July	135.0
JULY	67.93	123.35	1.04	Mid August	135.0
AUG	82.87	152.64	1.04	Mid September	130.0
SEPT	86.22	163.25	1.02	Mid October	130.0
OCT	28.24	34.67	0.67	3rd Week of December	152.0
NOV	42.96	72.88	0.92	3rd Week of January	148.0
DEC	45.45	77.67	0.98	2nd February	137.0
JAN	50.71	80.23	0.98	3rd Week Feb	125.0
CD at 5%	**NS**	**12.34**	**NS**	**……**	**11.42**

Table.5 Disease incidence as affected by the climate change effects from 2009-2017

Name of The Pests	2009	2010	2011	2012	2013	2014	2015	2016	2017
Makhana Aphid	NA*	Mild	Mild	Mild	Mild	Mild	Mild	Moderate at nursery	Moderate at nursery
Makhana Blight	NA*	….	Mild	Mild	Mild	Mild	Mild	Mild	Mild

NA* data are not available

Fig.1 Change in carbohydrate (%) synthesis at different growing season 2016-17

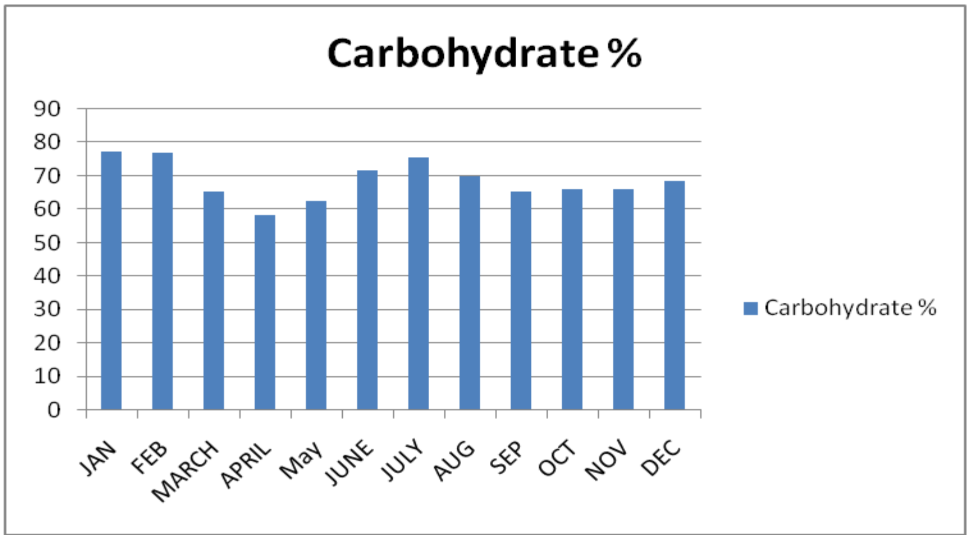


Fig.2 Change in protein (%) at different growing season 2016-17

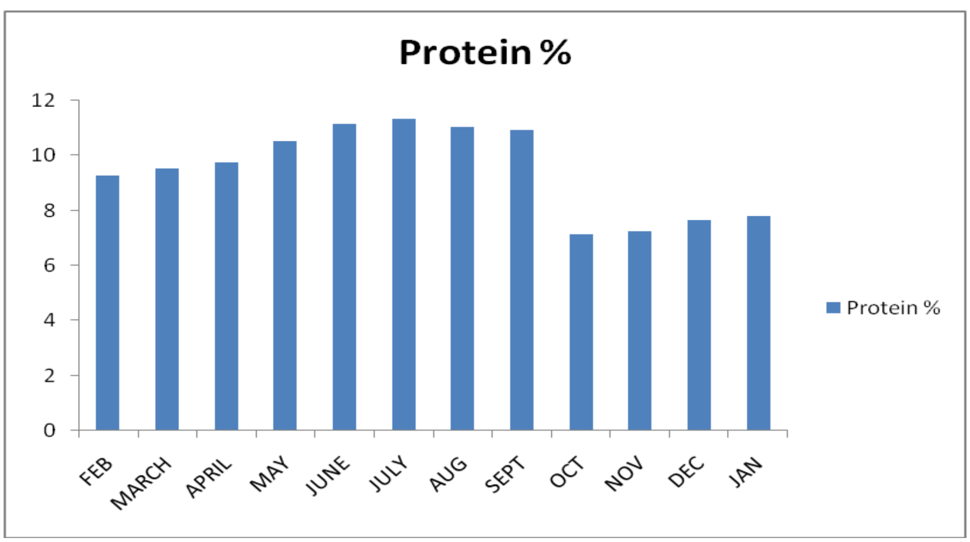
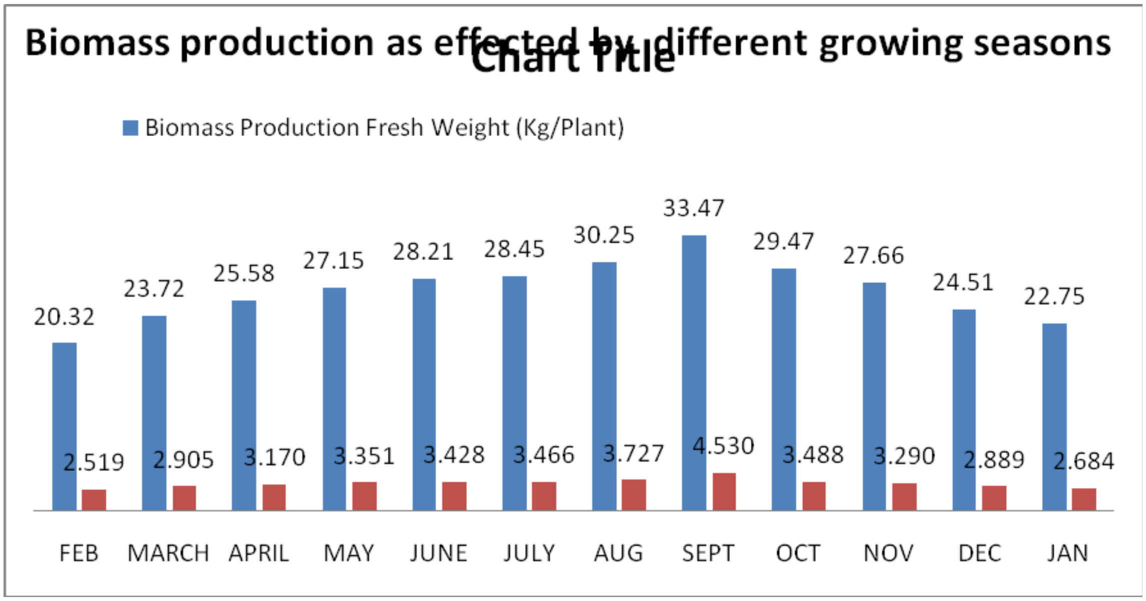


Fig.3 Biomass production of Makhana (Fresh and Dry) as affected by different growing seasons



Pest and diseases

Makhana aphid (*Rhopalosiphum nymphaeae*) has become more prominent pest of Makhana in recent years (Table 5). Aphid infestation was found during nursery stage of Makhana plant. It is also mentioned as one of the major pest of makhana by Mishra *et al.*, (1992) and Swaraswati *et al.*, (1990). Makhana blight (*Alternaria alternata*) is not a serious disease till now. It's infestation is relatively mild in both the nursery and mature makhana plant. Makhana blight disease was also reported by Hyder and Nath (1987), Dwivedi *et al.*, (1995).

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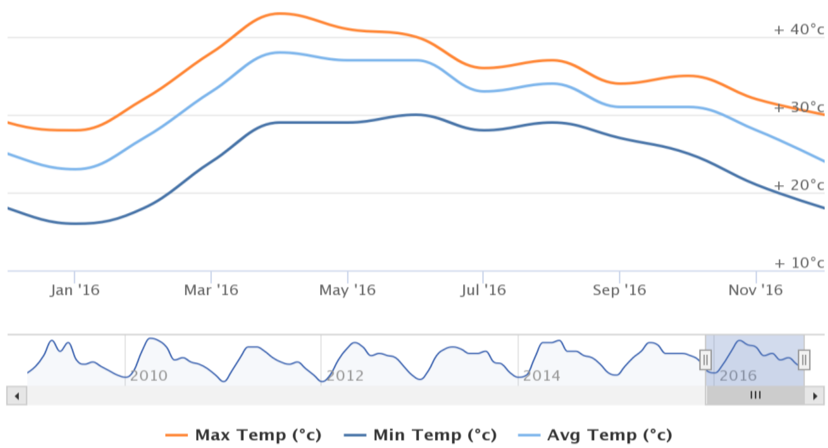
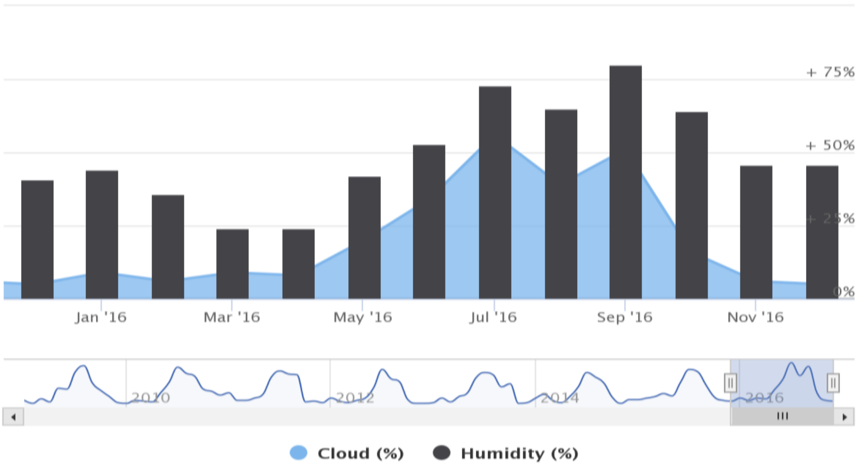
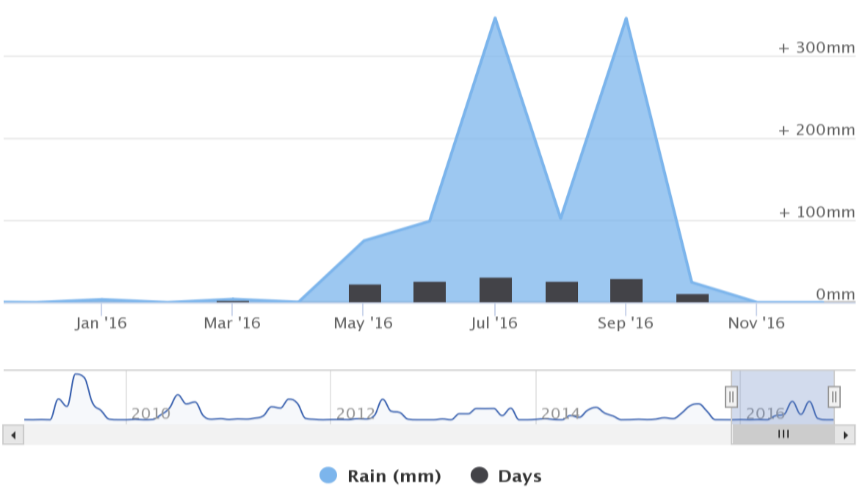
Appendix -1
Weather Reports of Darbhanga



(A) Changes in Temperature



(B) Changes in Humidity



(C) Changes in Rainfall

Table.1 Climate data of Darbhanga (2017) till crop harvest

Months (2017)	Temperatures (^0C)	Humidity (%)
JAN	17.0	78.0
FEB	22.0	65.0
MARCH	25.0	60.0
APRIL	30.0	54.0
MAY	31.0	61.0
JUNE	32.0	70.0