ISSN : 0974 - 7435 Volume 8 Issue 9

BioTechnology
An Indian Journal

FULL PAPER

BTAIJ, 8(9), 2013 [1251-1257]

Meteorological impact on peanut yield in China

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ABSTRACT

Weather conditions are essential for peanut growth. To understand the effect of weather on peanut yield, this paper uses 31 years (1981–2011) meteorological data (sunshine duration, rainfall and temperature) and peanut yield of ten provinces from China. Simple linear stepwise regression estimation was used to determine the relationship between peanut yield and weather as well as tendency during the life cycle. Except for trend yield, the weather factors' impact on peanut yield is significantly though some monthly weather variables are insignificant. We could forecast the yield according to meteorological yield coefficients, and we also use irrigation or film-covering to change weather condition to increase the peanut yield. This will give a theoretical basis for crop yield forecasting and the way to increase yield. In summary, this study could be used in the earlier warning for peanut yield. These results provide an important guiding and predicting bases for peanut yield.

KEYWORDS

Peanut yield;
Stepwise regression;
Meteorological factors;
China.

INTRODUCTION

There is a close relationship between climatic conditions and agricultural production[6]. The changes of climatic factors such as sunshine, temperature and rainfall led directly to the changes of light, heat and water which are desired by crop growth, which further led to the adjustment of the production areas, changes in the level of production and crop yield variation[1,3,4]. With in-depth research of climate change, extensive attention was paid to agro-meteorological resources, agricultural crop yield changes and other related issues[5].

Peanut is one of the important oilseed crops, not only full of nutritious, but more than 50% oil content. It is used in food, oil processing, study, printing and dyeing industry[8]. Planting range spanned 47^0 and 18^0 of north latitude, distributing from the northern temperate zone to tropical Hainan Island, from the western semi-arid areas to the east coast[2]

In this study, the parameters of the trend and weather to peanut yield would be resolved in provincial groups. The objectives of this study are to estimate the above parameters, which affect the crops yield in different growth stages. From the results, the peanut yield of the different provinces could be forecasted also suitable supervision to meet higher yield could be provided

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according to the weather condition.

The separation of trend yield from actual yield has been a common method in estimating agricultural crop yield[9]. used a simple Linear model to estimate trend and meteorological parameters in a single county of China; [7]used a Non-linear model to estimate for national level but in this study, we use simple linear model to estimate the peanut yield in different provincial region.

The structure of this study is in the following: part 1 is introduction, part 2 is data and its description, part 3 is the methodology, part 4 is the result and analysis, and the last is discussion and conclusion.

DATA AND ITS DESCRIPTION

Peanut production data during 1980-2011 was collected from the National Bureau of Statistics of China (http://www.stats.gov.cn/). This study selected the main peanut producing provinces from China regional representatives including the North, East, Central, and South. Top 10 Peanut main-producing provinces were selected from Chinese Bureau of Statistics according to peanut average-acreage in the last 10 years (2002-2011), and the studied area accounts for more than 85% of the nationwide peanut production. The acreage, output and yield are listed in TABLE 1.

TABLE 1 : Peanut acreage and output in China (2002-2011)

	Province	acreage		Production		Yield	
		(1000 ha)	Rank	(10^4 t)	Rank	(kg/ha)	Rank
Northeast	Hebei	413.4	3	136.3	3	3297	5
	Liaoning	223.3	6	55.7	8	2494	8
East	Anhui	212.9	7	79.4	5	3729	3
	Jiangxi	146.6	10	36.7	11	2503	7
	Shandong	847.1	2	345.2	2	4075	1
Central	Henan	970.1	1	363.2	1	3744	2
	Hubei	177.1	9	61.3	6	3461	4
South	Guangdong	317.0	4	80.9	4	2552	6
	Guangxi	194.1	8	45.6	10	2349	9
	Sichuan	258.4	5	58.1	7	2248	10
	Total	3760.1	-	1225.7	-	3260	-

Sources

National bureau of statistics

In the selected provinces, Henan and Shandong are the top two provinces in peanut-acreage and production, accounting for more than 50% of total production in 2011 and ensuring Eastern and Central region high production position in China.

The data of daily sunshine, rainfall and air temperature were obtained from the China Meteorological Data Sharing Service Center (http://cdc.cma.gov.cn). Provincial meteorological factors (sunshine duration, rainfall, temperature) mean from April to September (1980-2012) is shown below in TABLE 2.

Sources: arranging each stage's meteorological data according to Meteorological Data Sharing Service Center in China

Yield

The trend yield was estimated from actual yield (Figure 1 & Figure 2). The trend yield is the additional changes in yield from agricultural technological progress i.e. the non natural factors[9] such as improved or hybrid seed, better management system, extension services etc. According to the positive slope, technological impact to the yield is different to each province. Anhui, Shandong, Henan and Hubei have higher trend yield, for they have steeper slope.

Meteorological yield is the residual of actual yield and trend yield. The fluctuation gap between actual yield and trend yield demonstrates the influencing degree to the yield caused by the weather. Liaoning, Anhui, Shandong, Henan and Hubei have endured larger influence in peanut yield from the weather (Figure 1 & Figure 2).

TABLE 2 : The meteorological mean in selected provinces from April to September during 1980-2011

code		North		East			Central		South		
		Hebei	Liaoning	Anhui	Jiangxi	Shandong	Henan	Hubei	Guangdong	Guangxi	Sichuan
sunshine	Apr	8.0	7.6	5.6	3.8	7.7	6.3	4.8	3.3	3.3	5.5
(h)	May	8.5	8.0	6.1	4.8	8.1	6.6	5.3	4.6	4.8	5.5
	Jun	8.1	7.5	5.5	4.8	7.7	6.5	5.2	5.3	5.1	4.8
	Jul	7.0	6.2	6.1	7.3	6.3	5.7	5.9	7.0	6.1	5.0
	Aug	7.0	6.8	5.9	6.6	6.6	5.6	6.2	6.4	6.2	5.3
	Sep	7.5	7.7	5.3	5.5	7.1	5.2	5.0	6.0	6.0	4.1
rainfall	Apr	1.1	1.4	3.6	7.6	1.4	1.8	3.9	6.7	4.5	2.0
(mm)	May	1.9	2.2	4.3	7.7	2.4	3.6	5.1	8.9	7.7	3.4
	Jun	3.1	3.7	7.1	9.9	3.4	3.8	6.5	10.7	10.5	5.3
	Jul	5.3	6.2	7.7	5.9	6.1	6.2	7.4	8.3	9.6	6.6
	Aug	4.4	5.8	5.7	5.6	5.6	5.0	5.5	8.5	8.0	5.9
	Sep	2.2	2.5	3.4	3.7	2.8	3.3	3.6	6.4	5.1	4.6
temperature	Apr	12.3	9.9	15.2	17.3	12.6	15.2	16.1	21.5	21.3	12.5
(ºC)	May	18.5	16.4	20.4	21.8	18.1	20.3	20.8	24.7	24.6	16.1
	Jun	22.8	20.7	24.0	24.9	22.4	24.6	24.2	26.8	26.5	18.4
	Jul	24.6	23.4	26.7	28.0	24.7	26.0	26.7	27.9	27.4	19.8
	Aug	23.2	22.9	25.9	27.2	24.3	24.8	26.0	27.7	27.2	19.4
	Sep	18.3	17.6	21.8	23.7	20.3	20.4	22.0	26.3	25.6	16.4

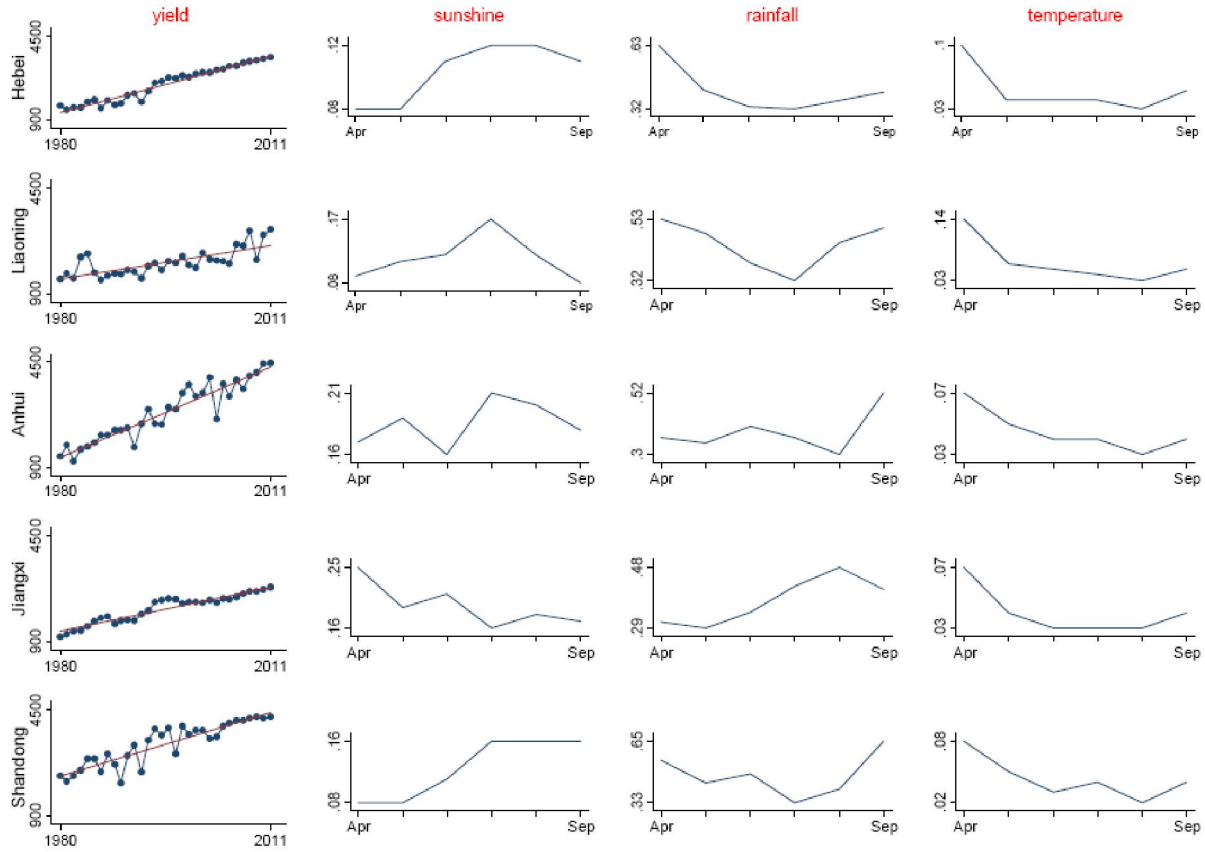

Figure 1 : The actual and trend yield, coefficient of variances of sunshine, rainfall and temperature in Hebei, Liaoning, Anhui, Jiangxi, Shandong of China(——trend; —◆—actual; ——variance coefficient).

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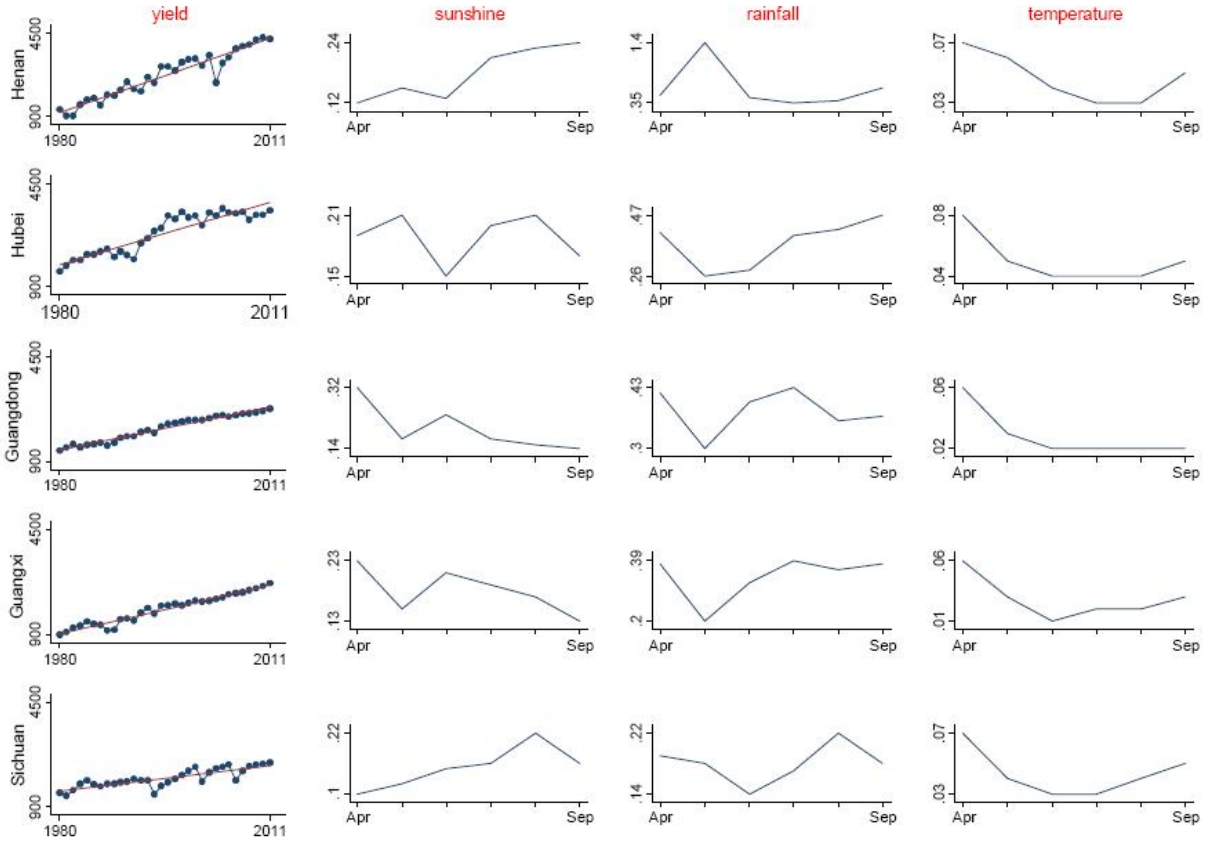

Figure 2 : The actual and trend yield, coefficient of variances of sunshine, rainfall and temperature in Henan, Hubei, Guangdong, Guangxi, Sichuan of China(——trend; —◆—actual; —— variance coefficient).

Weather

Sunshine

There is no much difference comparatively in the variation of sunshine hours throughout the 6-months of the past 31 years in the study areas. From the Mean of sunshine duration, the North has the longest sunshine duration, followed by the Central region, In the East with exception to Shandong sunshine duration (similar to the North) has similar sunshine duration as the South. In Hebei (North of China), Liaoning (Northeast) and Shandong (East), the range of average sunshine duration is 6.2 to 8.5 hours per day; the sunshine duration of Anhui, Hubei, Guangxi, Sichuan is 3.3 to 6.2 hours; Henan; Jiangxi and Guangdong range 3.3-7.3 hours. According to the coefficient of variance (CV), in April, Jiangxi, Guangdong and Guangxi have higher CV, and in May, Hubei has higher CV with 0.21; most selected provinces have higher CV in June to August.

Rainfall

In comparison to the other two meteorological factors, rainfall varies greatly in different years. Generally, there is less rainfall in sowing and harvesting season, and the North has less rainfall than other regions. The North has more rainfall in July and August with the range of 5.3 to 6.2 mm. The North including Shandong and Henan has higher CV for rainfall. Henan's rainfall is most unstable and Sichuan is relatively stable than other regions.

Temperature

Averagely, the South has stable mean temperature than other regions. The temperature in sowing season (April) is lower, higher in May to August, and tends a slight decreasing in September. The CV of temperature is comparatively lower than other two weather factors. In peanut life cycle, only Liaoning has highest CV in April with value of 0.14.

METHODOLOGY

The Trend yield from the various provinces in Figure 1 and Figure 2 are obvious, and the weather fac-

tors influencing peanut yield are possibly existing, so the equation to estimate the peanut yield is in the following (Equation 1).

$$Y_t = f(T, \sum_t X_t) \quad (1)$$

In the above equation, Y denotes peanut yield; t denotes selected year; parameter "T" explains the accumulated development of technology from improved seeds, farming management system, reflecting on the gradual increment on yield in time. Thus yield is the function of trend (T) and the weather factors X_i.

Based on above, China national peanut yield model is in the following (Equation 2).

$$Y_t = \eta T + \sum_t \alpha_t . ss_t + \sum_t \beta_t . rf_t + \sum_t \gamma_t . tm_t + cons. + \varepsilon \quad (2)$$

Therefore, sunshine duration, rainfall and temperature are denoted as ss, rf and tm respectively. And η, α, β and γ are the estimating parameters, measuring the degree of response to peanut yield with error term (μ_1). In addition, this study uses a 6-month peanut life cycle to explain the effect of the meteorological factors on yield.

RESULTS AND ANALYSIS

Figures 1 and Figure 2 show various results for the actual peanut yield in the selected provinces.

The coefficient of T is the parameters of trend yield, reflecting technological progress in annual trend yield (TABLE 3). Henan, Anhui, Hubei and Shandong have higher trend yield, ranging from 70 to 108 kg/ha annually.

In peanut life cycle, there are five stages: sowing, seedling, flowering, peg, pods and nut. The duration of one cycle is about 140-150 days. The stages in the life cycle require different weather conditions to meet peanut growth, but the changing weather condition often influence the peanut yield.

North and northeast region

Hebei peanut output forms about 93%-95% of the total output in the Northern region during 2000-2011(NBSC, 2013). The estimated stepwise regression equation of Hebei explains 98% of the variation in peanut yields. While the average 3.1 mm rainfall in June and 2.2 mm rainfall in September shows negative influence. The lesser rainfall (1.1mm) at the early peanut stage in April and relatively more 3.8mm rainfall in August have positive influence on peanut yield.

Liaoning on the other hand, constitutes 48-74% of the total peanut production in the Northeastern region of China duaring 2000-2011(NBSC, 2013).. The estimate of the regression model of this province shows a lower explanatory power of 76% compared to other provincial model. Form the Liaoning model, only sunshine and rainfall significantly affect yield with 7.7h sunshine depicting the strongest positively related impact on yield but the prolong sunshine (May; 8.0h and July; 6.2h) with the low rainfall in May (2.2mm) is not so good for yield increment.

East of China

The selected provinces from the eastern region, Anhui, Jiangxi and Shandong accounted for 81%-87% of total production of the region during 2000-2011(NBSC, 2013). The estimated stepwise regression equation from the above table explains 94%, 98% and 91% for the peanut yield of the aforementioned provinces respectively. Anhui experiences her highest impact on sunshine duration in April and July; positively relating to yield in April but otherwise in July with average sunshine hour of 5.6 and 6.1 respectively, another meteorological factor that relates negatively is the rainfall in July and September. The temperature in all the six months of Jiangxi province significantly affect yield. July and August exhibits the strongest impact on Jiangxi peanut yield; the average 28.0^{0}C in July not favoring yield but the 27.2^{0}C in August positively influence yield.

On the other hand, Shandong's highest impact is seen on sunshine in April and on temperature in August. Shandong is second (7.7 h) in terms of sunshine duration in April after Hebei province (8.0 h) and in these two areas the weather factor indicated a highly negative effect to yield.

Central region

Peanut production in Henan and Hubei of the Central region of China accounted for 91%-95% of total production in the region during 2000-2011(NBSC, 2013). The temperature in May has the strongest negative impact on peanut yield in Henan. Higher temperature shows positive signs in August to almost all the provinces including Henan which have an average temperature of 24.8^{0}C during the month. Another nega-

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TABLE 3 : China national peanut yield model, using trend and Meteorological factors

	Hebei	Liaoning	Anhui	Jiangxi	Shandong	Henan	Hubei	Guangdong	Guangxi	Sichuan
T	70.19 (4.7)	36.17 (5.39)	94.68 (5.87)	54.42 (2.53)	69.85 (5.38)	107.57 (6.6)	53.48 (6.91)	46.01 (1.33)	53.72 (1.9)	34.74 (2.59)
ss_Apr	--	--	103.69 (63.63)	--	-137.7 (71.28)	100.16 (63.31)	-214.28 (81.26)	52.84 (18.52)	--	--
ss_May	--	-149.79 (70.61)	-73.16 (47.13)	--	--	159.8 (95.53)	-95.61 (47.01)	--	--	--
ss_Jun	113.87 (35.49)	--	--	--	--	--	--	-15.88 (10.47)	-86.79 (21.96)	--
ss_Jul	-89.12 (48.61)	-123.09 (55.12)	-182.58 (57.7)	--	--	-118.16 (48.34)	-80.33 (41? 00)	-32.7 (20.22)	41.4 (22.31)	-100.3 (26.8)
ss_Aug	--	--	91.72 (56.58)	--	--	--	--	-99.93 (20.3)	--	--
ss_Sep	--	303.13 (103.34)	--	63.65 (24.5)	--	--	85.45 (54.32)	76.63 (19.08)	--	--
rf_Apr	212.97 (63.84)	148.01 (88.95)	--	-13.95 (9.26)	--	--	-95.94 (45.56)	9.88 (5.92)	27.57 (11.51)	--
rf_May	--	-183.14 (79.87)	--	--	--	--	--	--	--	224.12 (48.97)
rf_Jun	-76.71 (33.51)	--	--	31.38 (7.16)	103.43 (36.15)	--	--	--	--	90.35 (32.46)
rf_Jul	--	--	-112.37 (27.65)	-52.21 (17.79)	53.56 (25.74)	--	--	-14.07 (6.53)	--	--
rf_Aug	55.83 (17.42)	63.63 (22.61)	--	--	--	--	--	--	26.68 (9.91)	--
rf_Sep	-77.74 (31.05)	--	-73.51 (42.32)	--	--	-54.58 (29.31)	--	24.47 (5.92)	--	55.4 (30.52)
tm_Apr	--	--	--	-70.44 (19.78)	-109.06 (55.17)	--	210.84 (56.66)	--	--	-74.79 (30.67)
tm_May	--	--	--	57.62 (22.77)	--	-226.75 (84.06)	--	-36.06 (15.97)	-53.06 (22.62)	71.44 (34.64)
tm_Jun	68.67 (43.88)	--	--	103.86 (33.61)	--	--	--	--	174.85 (53.71)	--
tm_Jul	80 (45.9)	--	--	-255.23 (49.35)	--	--	--	--	-98.95 (48.07)	--
tm_Aug	--	--	--	130.72 (34.77)	231.71 (79.94)	243.48 (66.72)	123.05 (54.33)	138.12 (38.42)	--	-115.3 (25.46)
tm_Sep	-65.29 (39.57)	--	--	-47.56 (23.35)	--	--	--	-53.2 (24.16)	--	--
_cons	-1029.67	859.09	2735.84	3015.29	-979.44	-1369.21	-2868.76	2.2	232.79	2578.79
R^2	0.98	0.76	0.94	0.98	0.91	0.95	0.92	0.99	0.98	0.92

Estimation period 1981-2011

tively meteorological impact on Henan peanut yield includes higher millimeter of rainfall during September.

The early stage of peanut growth proves as one of the most important period in determining yield in Hubei province as indicated by the strongest positive and negative impact in April; lower temperature favoring the early plant but the less hours of sunshine (4.8h) in the province related negatively to yield.

South and southwestern region

From the South, Guangdong and Guangxi accounted for 93%-94% of total production in the region during 2000-2011(NBSC, 2013). A much larger portion compared to the share of the three provinces in the East. Guangdong peanut model explains a high percentage (99%) of the variation in peanut yield while Guangxi's explains 98%. Temperature and sunshine have the strongest impact on yield in these two provinces but at different months. In August, higher temperature improves yield and Guangdong experiences the highest

temperature (27.7^0 C) among these provinces..

The strongest meteorological impact experienced in Guangxi is temperature. The temperature in June (27.3^0 C) and July (28.1^0 C) are both the highest among other provinces but the estimated regression coefficient for July has negative influence on peanut yield.

Sichuan produces about 70%-76% of the South-western peanut production during 2000-2011(NBSC, 2013, http://www.stats.gov.cn/). Given the advantage of higher temperature to peanut yield in August as exhibited by other provinces, only Sichuan provinces experiences lower temperature that is less than 20^{0}C thus the meteorological impact related adversely to yield. While the average 3.4mm rainfall in May and relatively more rainfall 5.3mm in June and 4.6mm in September with the average temperature of 16.1^{0}C in May related positively to yield, the average sunshine of 5.0h in July shows an opposite relationship to yield.

DISCUSSION AND CONCLUSION

This section discusses the key reasons to the result of the interrelationship between peanut yield and the weather factors.

Weather conditions are essential for peanut growth. In recent years, climate change had a certain impact on the yield of peanut. This paper identifies the influence of meteorological conditions on the growth of peanut in different provinces in China, which has a certain guiding significance to the reasonable prediction of peanut yield.

The weather coefficients to yield listed in TABLE 3. We found that some monthly weather factors are not significant; the feasible reason is that the fluctuation of weather could meet the requirement of peanut growth, and would not influence the yield significantly. From the authors' opinion, even though their coefficients are not significant, the variables are considered important to crop yield, for example the temperature parameter in Liaoning province was not significant but the temperature is important to peanut growth.

In some provinces there are consistent weather conditions and it was expected that there should be comparable estimated result but we found otherwise. The author's opined that these differences could be caused by number of factors such as the variety of seed, soil quality etc. An example of this situation is found in July in the Guangxi (south) and Anhui (east) where they both show relatively similar hours of sunshine but exhibits different signs. Similar feature shared by the provinces and showing similar result is the high temperature in August (peanut pod-stage) which favors peanut growth.

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