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RELATIONSHIP BETWEEN LUNAR LIGHT AND POPULATION OF *Helicoverpa armigera* (Hub.) MOTHS AT GHARBIA GOVERNORATE

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ABSTRACT

This work aimed to study the relationship between phases of lunar lighting and population peaks of American bollworm (ABW), *Helicoverpa armigera* (Hub.) moth. It was carried out at Zefta district, in Gharbia Governorate, Egypt during four successive cotton seasons (2005-2008), Results showed that of *H. armigera* moths population had five to six peaks per season. At Gregorian months, moth peaks occurred at different dates per month, during the four seasons. Whereas, at lunar months, they occurred at constant moon phases (at the new moon or at the first quarter every month) in the same seasons. The scoto phase period (new moon) had a positive effect on the activity of moth populations, while, a negative effect was during the highest luminosity (full moon). The relationships between the percentages of moon light and moth populations were, in general, negative and highly significant and led to a linear regression equation. This information, cold aid the decision makers to better except the timing of the highest moth populations that produces different stages of this pest and reduces / eliminate their damage to cotton plants using available control methods.

Keywords: *Helicoverpa armigera*, Lunar, Gregorian months and Lunar phases.

INTRODUCTION

American bollworm (ABW) *Helicoverpa armigera* (Hb.) is one of the most important economic insect pest in Egypt (Ibrahim *et al*., 1994; Ragab, 1999 and Nada *et al.*, 2004) and in many parts of the world (Fitt, 1989).This insect is highly polyphagous. Eggs and /or larvae have been recorded on more than 60 plant species belonging to 47 families including maize, sorghum, tomato, Lucerne, tobacco, cotton clover and cowpea. Direct damage to flowering and fruiting structures by larvae and extensive periodic sprayed insecticides resulted in low yield and high control costs. Many investigations suggested that generation's cycles of ABW are synchronized by lunar cycles, independently of host plant phenology, climatic factors and accumulated heat units (Zalucki *et al*., 1994 and Nada & Ragab, 2010). An inverse relationship has been established between light trap catches of ABW moths and moon light with the highest trap catch occurring during new moon and lowest during full moon (Nemec, 1971; Agee *et al*., 1972; Bowden, 1973; Hartstack *et al*., 1973 and Youssef & Ismail,1999). Dufay(1964) and Bowden & Church (1973) established the hypoth of the competition between the light-trap and the lunar luminosity. They reported that the global lunar luminosity fraction could be represented by ten intervals; the phase at the end of these ten classes could be reported as a function of one lunation days/ month (29day &13Hrs). The curve showed that the first and 10th phases occurred during seven days form each one. On the other hand, Gyorfi (1948) attributed that the much smaller number of insects caught by light traps at full moon to decreased activity. Nemec (1971) reported that in his laboratory studies (in bioclimatic chambers) on the effects of various photoperiods and low light intensities on bollworm moth activity confirm the theory of moth activity suppression by moonlight. The present work aims to study the relationship between lunar light and population of American bollworm *H. armigera* moth.

MATERIALS AND METHODS

The present study was carried out at a private farm located in the Village of Kafr El-Guindy, Zefta district, Gharbia Governorate, in an aggregation of cotton about 50 feddan, during four successive cotton seasons (2005 to 2008). The fields were sown by the Egyptian cotton, *Gossypium barbadense* (L.) variety Giza 89 during 2005 and 2006, and variety Giza 86 during 2007 and 2008 cotton seasons. Cotton cultivated dates ranged between the second half of March to the first week of May. The experimental area was subjected to normal agricultural practices. The applied cotton pest control procedures were according to the Ministry of Agriculture cotton pest control program. Cotton fields were surrounded by clover, wheat and vegetables during the winter seasons prior to the cotton, and with maize and vegetables during the summer seasons.

One light trap, modified by Hosny (1958), was set on the roof of a village house six meters above the ground near the cotton fields. The light trap catches were collected and sorted to species and the collected of *H. armigera* adults were counted every week. The whole data of the four seasons were converted to daily catch. The experimental periods extended from the first week of April to the last week of September throughout the four cotton seasons of 2005-2008. To determine the population fluctuations of *H. armigera* adults, the data was represented graphically. It was plotted according to lunar and Gregorian months. Every lunar month consists of four moon phases, the first quarter (FQ), full moon (FM), last quarter (LQ) and new moon (NM) (Bowden, 1973). It corresponds to the visible moonlight percentages of 50, 100, 50 and 0%, respectively. Also, these moon phases correspond 7^{th} , 15^{th} , 21^{st} and 29^{th} or 30^{th} of the lunar month, respectively (Fig. 1). Daily data divided into two halves according to the visible moonlight percentages. The first halve from 1 to 15 and the second from 16 to 29 or 30 of the lunar month which corresponded with moonlight percentages of 1 to 100% (FQ- FM) and of 99 to 0 % (LQ- NM), respectively. Each halve of the lunar month is called period which was subjected to statistical analysis to determine the relationship between the percentages of the visible moonlight and number of *H. armigera* adult catch.

The percentages of visible moonlight were obtained from the site (Calendar-365.com). Data in (Fig.1) show that moon lighting ratios during the lunar cycle is going through four main phases.

fig

RESULTS AND DISCUSSION

The seasonal fluctuations of *Helicoverpa armigera* moths, the actual numbers of *H. armigera* moths for the experimental period in the four seasons are graphically illustrated in (Fig. 2) and (Table 1). Data were plotted according to Gregorian and lunar months.

Table (1): Peaks occurrence of *Helicoverpa armigera* (Hub.) moths per trap according to lunar cycles and Gregorian calendar during four successive cotton seasons

Generation / Season	The first		The second		The third		The fourth		The Fifth		The sixth	
	Lunar cycles	A.D.	Lunar cycles	A.D.	Lunar cycles	A.D.	Lunar cycles	A.D.	Lunar cycles	A.D.	Lunar cycles	A.D.
2005	NM	8/5	NM	7/6	NM	6/7	NM	5/8	NM	4/9		
2006	FQ	4/5	NM	27/5	NM	25/6	NM	25/7	NM	24/8	NM	22/9
2007	NM	17/4	NM	17/5	NM	15/6	NM	15/7	NM	14/8	NM	12/9
2008	FQ	13/5	FQ	11/6	FQ	11/7	NM	3/8	FQ	8/9		

A.D., Gregorian calendar
New moon: NM, First quarter: FQ

In Gregorian months, the experimental periods extended from the first week of April to the last week of September throughout the four cotton seasons of 2005-2008. Data showed that in 2005 season, the population of *H. armigera* moths occurred in five peaks. The appearance date of each peak was 8/5, 7/6, 6/7, 5/8 and 4/9. In 2006 season, the population occurred in six peaks. The appearance date of each peak was 4/5, 27/5, 25/6, 25/7, 24/8 and 22/9. In the third season of 2007, six peaks of the population were recorded and the date of occurrence for each peak was 17/4, 17/5, 15/6, 15/7, 14/8 and 12/9. Throughout 2008 season, it was occurred in five peaks, at 13/5, 11/6, 11/7, 3/8 and 8/9. Aaccording to Gregorian months, the population of the *H. armigera* moths per trap in the experimental periods occurred in five to six peaks per season at different dates per month, throughout the four seasons of the experimental period (Table1).

When using the lunar months to interoperate the data they showed that in 2005 season, the *H. armigera* moth population was recorded in five peaks appeared at the new moon phase. In 2006 season, the population occurred in six peaks; the first at the FQ moon phase and the other five at the NM moon phase. In 2007 season, the population occurred in six peaks that occurred at the NM moon phase. In 2008 season, the population occurred in five peaks. The moon phases for each peak were at FQ, except at the fourth the peak was at the NM moon phase. The number of *H. armigera* moths peaks, according to the lunar cycles, were five to six per season in constant moon phases, at the end of lunar month (the NM) and at the FQ of the next lunar month (Table 1).

Data in (Fig. 1) showed that the percentages of the visible moon light differed in the four phases. The LQ in the previous lunar month and the NM in the next one had the lowest percentage of the visible light of the moon. It decreases irregularly from 50 % at the 21st day of lunar month to 0% at the 29th day or the 30th . Then, it increases also irregularly to 35%.This period was extended for 15-16 days, from the twenty-one day in the previous lunar cycle to the sixth day in the next lunar cycle (LQ to NM), contained the longest period of the scoto phase. The FQ and the FM in the lunar cycle had the highest percentage of the visible light. It increased irregularly from 50 % in the FQ of moon light to 100% in the FM and decreased also irregularly to 75%.This period was spanned for 14 days, from the seventh day to the twentieth day in the lunar cycle (FQ to FM). It contains the longest period of phases of the lunar lighting and the highest luminosity (Fig. 1).

The relationship between the visible percentages of lunar phase light and moths catch. Results obtained in Tables (2-5) showed the simple correlation and regression equations values established between the visible percentages of lunar light cycle (independent factor) and moth populations of *H. armigera* per trap (dependent factors). In 2005 season, Data in (Table 2) cleared that the experimental periods were thirteenth period. The simple correlation (*r*) values were highly significant negative correlation except in the periods 2 and 11 that were highly significant positive correlation. The periods 1 and 13 were incomplete periods. The *r* values were ranged between -0.9216 and 0.9314. The slope values of the simple regression were 0.0000, 0.0011, -0.0181, -0.0130, -0.0247, -0.0296, -0.0186, -0.0247, -0.0792, -0.0750, 0.0118, -0.0087 and 0.0000 for the thirteenth period, respectively.

Table (2): Relationships between the percentage of the visible of the moonlight and *Helicoverpa armigera* (Hub.) moths indicated by Gregorian calendar and lunar cycles during 2005 cotton season

Lunar cycles periods	Gregorian calendar				Lunar phases	Percentages of moonlight		simple correlation	Equation parametrs	
	From		To			From	To		a	b
1	April	1	April	9	NM --	53	1	0	0	0
2	April	10	April	24	FQ -FM	1	100	0.6520	0.113	0.0011
3	April	25	May	8	LQ-NM	99	0	-0.9074	2.067	-0.0181
4	May	9	May	23	FQ -FM	1	100	-0.8768	2.164	-0.0130
5	May	24	Jun	7	LQ-NM	99	0	-0.8796	3.281	-0.0247
6	Jun	8	Jun	22	FQ- FM	1	100	-0.7545	4.864	-0.0296
7	Jun	23	Jul	6	LQ-NM	99	0	-0.8876	3.604	-0.0186
8	Jul	7	Jul	21	FQ -FM	1	100	-0.8997	3.282	-0.0247
9	Jul	22	Aug.	5	LQ-NM	99	0	-0.8960	8.163	-0.0792
10	Aug.	6	Aug.	20	FQ -FM	1	100	-0.9216	9.664	-0.0750
11	Aug.	21	Sept.	4	LQ-NM	99	0	0.9314	0.993	0.0118
12	Sept.	5	Sept.	19	FQ -FM	1	100	-0.8558	0.898	-0.0087
13	Sept.	20	Sept.	29	NM--	99	21	0.0000	0.000	0.0000
n= 13, *r* values at P 0.05= 0.5139 and at P 0.01= 0.6411										

In 2006, results in (Table 3) showed that the experimental periods were also thirteenth period. The simple correlation values were highly significant negative correlation except in the periods 1, 12 and 13 that were incomplete periods. Also, the *r* values were ranged between -0.9248 and -0.7186. The slope of the simple regression values were 0.000, -0.002, -0.003, -0.012, -0.013, -0.036, -0.023, -0.012, -0.031, -0.024, -0.045, 0.000 and 0.000 for the thirteenth periods, respectively. In 2007, (Table 4) showed that the periods were twelve period. The simple correlation values were negative correlation except in the period 11 that was positive. Also, it was highly significant correlations in the all periods except the periods 2, 8, 9 and 11 that were insignificant. The *r* values were ranged between -0.919 and 0.452. The slope values of the simple regression values were -0.0081, -0.0031, -0.0169, -0.0139, -0.0232, -0.0258, -0.0255, -0.0058, -0.0113, -0.0176, 0.0031and -0.0111 for the twelve period, respectively. In 2008, (Table 5) indicates that the periods were also twelve period. The *r* values were negative in the all periods except the periods 8, 10 and 12 that were positive. Also, it was highly significant at negative positive correlations except the period 10 that was insignificant correlation. The *r* values were ranged between -0.884 and 0.869. Also, the slope values of the simple regression were ranged between -0.0054 and 0.01.

Table (3): Relationships between the percentage of the visible of the moonlight and *Helicoverpa armigera* (Hub.) moths indicated by Gregorian calendar and lunar cycles during 2006 cotton season

Lunar cycles periods	Gregorian calendar				Lunar phases	Percentages of moonlight		simple correlation	Equation parametrs	
	From		To			From	To		a	b
1	April	1	April	13	FM --	53	1	0.0000	0.000	0.000
2	April	14	April	27	LQ-NM	99	0	-0.8747	0.296	-0.002
3	April	28	May	12	FQ -FM	1	100	-0.8050	0.459	-0.003
4	May	13	May	27	LQ-NM	99	0	-0.7478	1.314	-0.012
5	May	28	Jun	11	FQ- FM	1	100	-0.9248	2.703	-0.013
6	Jun	12	Jun	25	LQ-NM	99	0	-0.9245	4.668	-0.036
7	Jun	26	Jul	10	FQ –FM	1	100	-0.8667	5.462	-0.023
8	Jul	11	Jul	25	LQ-NM	99	0	-0.8930	3.930	-0.012
9	Jul	26	Aug.	9	FQ –FM	1	100	-0.7186	4.987	-0.031
10	Aug.	10	Aug.	24	LQ-NM	99	0	-0.8807	3.442	-0.024
11	Aug.	25	Sept.	8	FQ –FM	1	100	-0.7896	6.225	-0.045
12	Sept.	9	Sept.	22	LQ-NM	99	0	0.0000	0.000	0.000
13	Sept.	23	Sept.	29	---FQ	99	21	0.0000	0.000	0.000
n= 13, *r* values at P 0.05= 0.5139 and at P 0.01= 0.6411										

Table (4): Relationships between the percentage of the visible of the moonlight and *Helicoverpa armigera* (Hub.)) moths indicated by Gregorian calendar and lunar cycles during 2007 cotton season

Lunar cycles periods	**Gregorian calendar**				**Lunar phases**	**Percentages of moonlight**		**simple correlation**	**Equation parametrs**	
	From		To			From	To		a	b
1	April	3	April	17	LQ-NM	99	0	-0.9078	1.3	-0.0081
2	April	18	May	2	FQ -FM	1	100	-0.436	1.1	-0.0031
3	May	3	May	17	LQ-NM	99	0	-0.844	2.5	-0.0169
4	May	18	Jun	1	FQ- FM	1	100	-0.912	2.6	-0.0139
5	Jun	2	Jun	15	LQ-NM	99	0	-0.803	5.3	-0.0232
6	Jun	16	Jun	30	FQ -FM	1	100	-0.871	4.0	-0.0258
7	Jul	1	Jul	15	LQ-NM	99	0	-0.773	4.4	-0.0255
8	Jul	16	Jul	30	FQ -FM	1	100	-0.259	2.4	-0.0058
9	Jul	31	Aug.	14	LQ-NM	99	0	-0.356	4.8	-0.0113
10	Aug.	15	Aug.	29	FQ -FM	1	100	-0.706	2.8	-0.0176
11	Aug.	30	Sept.	12	LQ-NM	99	0	0.452	1.5	0.0031
12	Sept.	13	Sept.	27	FQ -FM	1	100	-0.919	1.2	-0.0111
n= 13, *r* values at P 0.05= 0.5139 and at P 0.01= 0.6411										

Table (5): Relationships between the percentage of the visible of the moonlight and *Helicoverpa armigera* (Hub.) moths indicated by Gregorian calendar and lunar cycles during 2008 cotton season

Lunar cycles periods	Gregorian calendar				Lunar phases	Percentages of moon light		simple correlation	Equation parametrs	
	From		To			From	To		a	b
1	April	7	April	21	LQ-NM	1	100	-0.884	0.59	-0.0054
2	April	22	May	6	FQ -FM	99	0	-0.873	1.17	-0.0063
3	May	7	May	21	LQ-NM	1	100	-0.884	2.50	-0.0147
4	May	22	Jun	4	FQ- FM	99	0	-0.869	2.03	-0.0063
5	Jun	5	Jun	19	LQ-NM	1	100	-0.884	4.94	-0.0317
6	Jun	20	Jul	4	FQ -FM	99	0	0.873	3.27	0.0100
7	Jul	5	Jul	19	LQ-NM	1	100	-0.884	5.13	-0.0308
8	Jul	20	Aug.	3	FQ -FM	99	0	0.154	3.49	0.0032
9	Aug.	4	Aug.	18	LQ-NM	1	100	-0.884	4.32	-0.0257
10	Aug.	19	Sept.	1	FQ -FM	99	0	0.869	1.79	0.0070
11	Sept.	2	Sept.	16	LQ-NM	1	100	-0.884	4.23	-0.0319
12	Sept.	17	Sept.	29	FQ -FM	99	0	0.865	0.42	0.0009

n= 13, *r* values at P 0.05= 0.5139 and at P 0.01= 0.6411

In general, the relationships between the percentages of the moon light and *H. armigera* moths catch were significantly high negative correlation and it has led to linear regression equation.

As mentioned before, moon lighting ratios during the lunar cycle is going through main four phases, which were NM, FQ, FM and LQ. The scoto phase period was at NM and the highest luminosity was at FM. And, the number of the ABW moths in the four seasons was occurred in five to six peaks per season in constant phases of lunar cycle. These constant phases were of end of the lunar cycle (NM) and the FQ of the next lunar cycle, which are, in general, compatible with the scoto phase. This meant that, the population of moths prefers the dark times for its activity. Also, the lowest number of the ABW moths was appeared in periods of FQ to FM that had the highest luminosity of the moonlight. Moth populations' activities do not favor the highest luminosity (Figs. 2 and 3).The highest percentages of moon light of had led to negative effect on *H. armigera* activity with positive effect in the lowest luminosity.

These results are consistent with Dufay (1964) who reported that the luminosity of FM at zenith is $3*10^3$ w/m^2 it reduced to $6*10^{-3}$ w/m^2 by the atmosphere absorption. He expressed that the lunar luminosity of zenithal distance "in summer are 0.2 lux during the FM, decreased 5times during 5days before or after FM. The sky during the NM (No moon, but there are its stars) has a Natural Nocturnal Luminosity. Luminosity was more weakly 140 times than during FM (about 350-500nm.). Bowden (1973) fixed up the hypothesis of the competition between the light-trap and the lunar luminosity (Shrivastava *et al*., 1987 and Bowden & Church, 1973). Also, an inverse relationship has been established between light trap catches of ABW moths and moon light with the highest trap catch occurring during new moon and lowest during full moon (Nemec, 1971 and Agee *et al*., 1973).

Fig2

fig3

Shrivastava *et al*. (1987) reported that a significant linear relationship between the degree of moon phase and the size of light trap catches of *Spodoptera litura* (Fab.). The catches were more around new moon ± 3days period as compared to the full moon ± 3days. The same results on *Agrotis ipisilon* (Huf.) and *Operophthera brumata* (L.) were obtained by Nag, 1991 and Lasazlo *et al*., 2012. On the other hand, Gyorfi (1948) attributed that the much smaller number of insects caught by light traps at full moon due to decreased activity. Nemec (1971) reported that in his laboratory studies (in bioclimatic chambers) on the effects of various photoperiods and low light intensities on bollworm moth activity confirm the theory of moth activity suppression by moonlight.

This information could aid the decision makers to better expect the timing of the highest moth populations that produces different stages of this pest and reduces / eliminate their damage to cotton plants using available control methods.

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العلاقة بين ضوء القمر و تعداد فراشات هليكوفيربا أرميجرا(دودة اللوز الأمريكية) فى محافظة الغربية

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معهد بحوث وقاية النباتات – مركز البحوث الزراعية الدقى جيزه- مصر

أجريت هذه الدراسة في حقول القطن في مركز زفتى بمحافظة الغربية خلال أربعة مواسم متتالية بداية من 2008 - 2005 ميلادية، لدراسة العلاقة بين مراحل إضاءة القمروتواجد قمم تعداد فراشات دودة اللوز الأمريكية فى المصيدة الضوئية. أشارت النتائج الي أن قمم تعداد فراشات دودة اللوز الأمريكية تتواجد خلال الموسم الواحد فى أربعة الى ستة قمم، ففي التقويم الميلادى، تواجدت قمم تعداد الفراشات فى تواريخ مختلفة فى المواسم الأربع، بينما فى الدورات القمرية، تواجدت قمم التعداد فى مراحل ثابتة، كانت فى مرحلتى بداية تواجد القمر والربع الأول فى المواسم الأربع. فترة مرحلة الإظلام كان لها تأثير إيجابى على نشاط فراشات دودة اللوز الأمريكية بينما كان التأثير سلبى عليها فى مرحلة الإضاءة العالية. كما وجد ان العلاقة بين النسب المئوية لضوء القمر ونشاط الفراشات كانت علاقة سالبة وعالية المعنوية بصفة عامة، وبالتالي تم انشاء معادلة خط الانحدار. من هذا العمل، يستطيع متخذ القرار أن يتوقع أعلى أو أقل تعداد من الفراشات التي تؤدي إلى وجود مختلف الأطوار ويتوقع أيضا الأضرارالناجمة ، وهذا ما يجعله يستطيع إتخاذ القرار الصحيح لتنفيذ إجراءات المكافحة للآفة

قام بتحكيم البحث

أ.د / عبد البديع عبد الحميد غانم	**كلية الزراعة – جامعة المنصورة**
أ.د / وحيد محمود حسين دسوقى	**مركز البحوث الزراعية**

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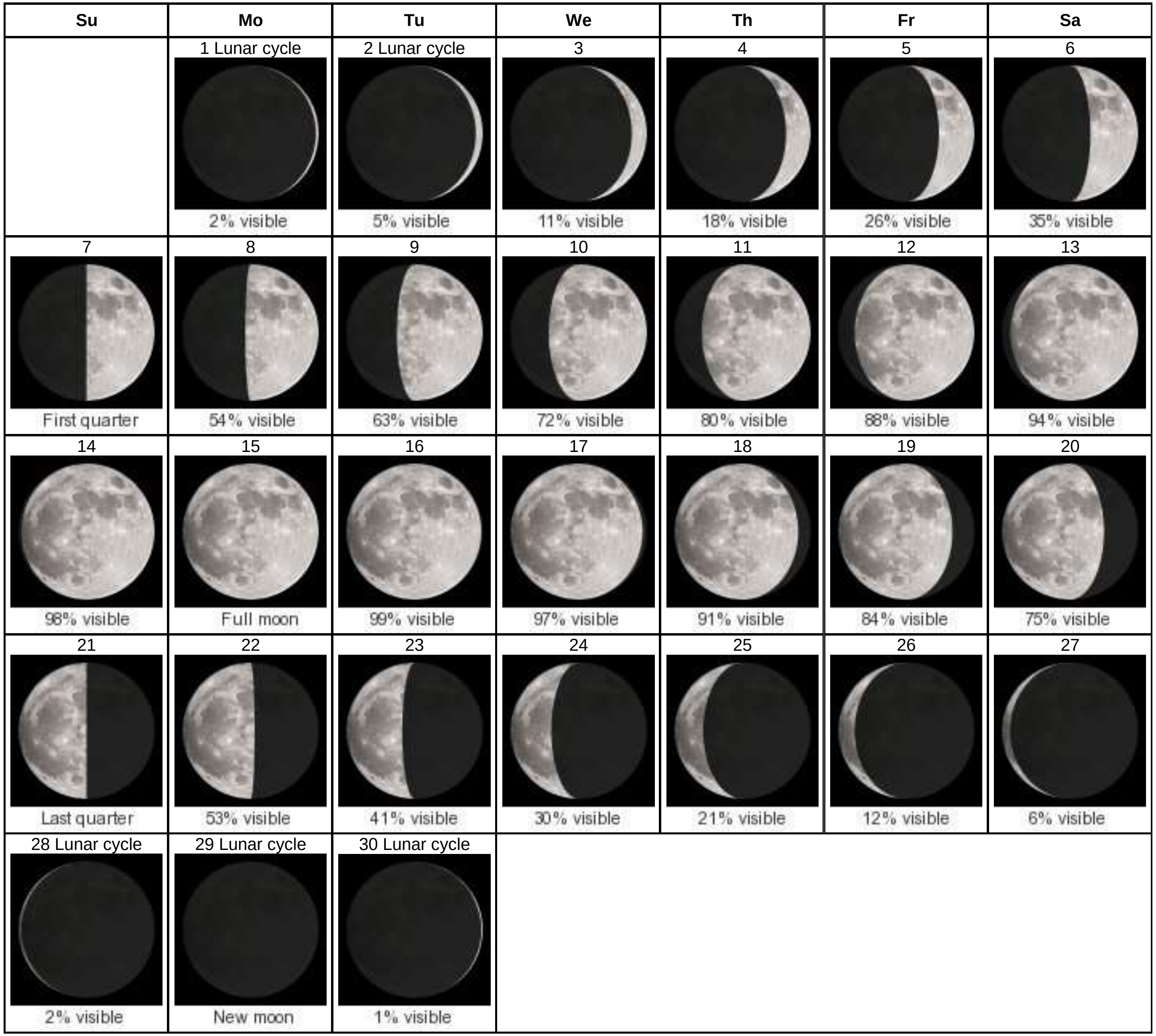

Fig. (1): The percentages of Moon lighting in Lunar cycle 29 or 30 days