Biological Agriculture and Horticulture, 2001, Vol. 19, pp. 247–259
0144-8765/01 $10

Printed in Great Britain

Evidence for Lunar-Sidereal Rhythms in Crop Yield: A Review

Nicholas Kollerstrom[1]* and Gerhard Staudenmaier[2]

[1]9, Primrose Gardens, London NW3 4UJ, U.K . [2]Knappertsbuschstr. 18, Munich, Germany

ABSTRACT

In 1956, Thun developed a procedure of sowing according to the position of the Moon in front of the twelve zodiacal constellations. These constellations were classified into four groups according to the element (Earth, Water, Air and Fire) astrologically associated with them. Root, leaf, flower and fruit crops were found to show increased yields if sown when the Moon stood before Earth, Water, Air and Fire constellations, respectively. Thun's philosophy of sowing by this sidereal rhythm has become a major component of biodynamic planting calendars, even though the founder of biodynamic agriculture, Rudolf Steiner, had only mentioned positive effects of the Full Moon in an agricultural context. In 1990, Spiess published a three-year study claiming to find effects of other lunar rhythms but not those of the 27-day sidereal month. This paper reviews published confirmations of the 'Thun effect' and reanalyses data concerning planting times and crop yields from Spiess's study with radish and carrots, by computing yield values as deviations from a moving average rather than as deviations from seasonal trends estimated by quadratic functions. The re-analysis showed an increase (ca +7%) in the yield of radishes which were sown in Earth constellations for his 1982 trial, with a comparable result demonstrated on re-analysing data from three years of carrot trials.

INTRODUCTION

The suggestion that crops should be sown at different times during the lunar cycle, to test traditional lore on the subject, may first have been made by Francis Bacon (Bacon, 1627). He was concerned with the lunar phase ('synodic') cycle of 29.5 days. Twentieth-century experiments along the lines suggested by Bacon have generally been equivocal (Kolisko, 1936; Mather, 1942; Beeson, 1946). While there is evidence that parameters such as germination rate (Maw, 1967), water absorption (Brown & Chow, 1973) and metabolism (Brown, 1960) respond to this cycle, it does not in general seem to affect crop yield

*Corresponding author – nk@astro3.demon.co.uk

(Kollerstrom, 1980). Researchers at the Sorbonne University found that the volume of plant DNA in cell nuclei tended to alter in relation to the synodic cycle (Rossignol *et al.,* 1990), indicating a possible link between seed fertility and the lunar month. There is also evidence that tree bud morphology is responsive to fortnightly lunar rhythms (Edwards, 1993).

The Biodynamic movement was founded by Steiner in 1924 as a form of organic farming whose approach would cognize the condition of the heavens (Koepf, 1989; Sattler & Wistinghausen, 1992). Steiner affirmed that the Moon, especially in its synodic cycle, was of great importance for the growth of crops (Steiner, 1993). In another context he advised that attention should be given to ecliptic constellations, rather than the tropical zodiac of astrologers.

Time-trial sowing experiments began in the 1930s within the Anthroposophical movement (founded by Steiner), whereby twelve batches of one type of crop were sown under similar conditions through a sidereal month, one per Moon-constellation, comparing their growth (Hachez, 1935). This month has 27 days, so one sowing was made per 2–3 days. In 1956 Thun developed what may be called the 'Thun theory', whereby crops were differentiated into the four categories of root (e.g., potatoes, radish), leaf (e.g. lettuce, spinach) flower and fruit/seed (Thun 1991, 1999). This emerged initially from her Moon-constellation sowing trials using radish. She linked each of these four crop types to the four elements, and thereby to the elements of the constellation-zodiac in which the Moon stood at the time of sowing. Whereas Hachez had studied possible effects of individual constellations, Thun viewed an underlying four-element-rhythm as primary.

There were, Steiner had claimed, four types of 'formative force' that worked in the realm of nature. These, he said, did not work centrically as the forces known to modern physics, but rather worked via form, and he called these forces 'etheric' (Wachsmuth, 1932). This was a reformulation of the ancient doctrine of the four elements, conceiving them as process rather than as substance. Within the Anthroposophical movement, botanical studies of plant morphology by Bockemühl have supported the view that the stages of plant growth may be seen in terms of such 'formative forces' that are linked with the traditional four elements. He has related the stages of leaf, flower and seed formation with water, air and warmth (Bockemühl, 1985).

The Thun theory used the tradition of the four elements embedded in the zodiac, linked to Steiner's notion of four types of formative force working in nature, by the lunar motion against the constellations, but using unequal constellation-boundaries, allocating for example 45° of the ecliptic to the large Virgo constellation and only 18° to the adjacent constellation of the Balance. Biodynamic calendars nowadays refer to these Moon-constellation elements as root days, leaf days, flower days and fruit or seed days, as linked respectively to the traditional elements earth, water, air and fire. This sequence recurs every nine days, thrice per lunar orbit, and forms the backbone of modern biodynamic calendars. Especially in Germany, biodynamic experts have expressed unease about these sidereal element-rhythms in the calendars, viewing them as inappropriate and lacking endorsement from Steiner (Koepf *et al.,* 1996).

Crop yield experiments were conducted by Thun in collaboration with the statistician Heinze over the eight years 1964–71, mainly with potatoes, but also with carrots and radishes, and beans as a seed-crop (Thun & Heinze, 1979). In these experiments, twelve rows of a crop were sown over one sidereal month, one row per 2–3 days, while the Moon traversed a particular constellation. Final crop yield weights were compared, measuring the total yield per row of potatoes or of beans. The weight ratio of the crop/total plant was also evaluated.

Such 'constellation' experiments for radish involve each row being grown for the same duration, by harvesting them over a similar 27-day schedule as was used for their sowing; for beans, several harvests were taken per plant and cumulative weight yield totals thereby obtained per row; while for potato sowing trials, harvesting and weighing were done for the twelve rows on the same day at the end of the growing season. Results from these trials, as published by Thun and Heinze, seemed uniformly positive, with yield maxima appearing in the predicted 'trigon' or Moon-constellation-element of sowing dates. The term 'trigon' refers to the three constellations of similar 'element' as form a triangle in the zodiac.

In 1962, the Thun theory became embodied into a biodynamic gardening calendar which has appeared yearly ever since (Thun, 2001) and is presently translated into 21 languages. This calendar incorporates various lunar cycles and events, for example it recommends no sowing over eclipses, evidence for which remains scant. Only for the 'Thun effect' does repeatable and statistically significant evidence exist. In the U.S.A., the 'Kimberton Hills' agricultural calendar more or less duplicates the Thun calendar in its recommendations, presently selling 6000 per annum. Its editor Wildfeuer began it after her participation in a Swiss experiment on carrot-growing trials as a test of the Thun-effect (Wildfeuer, 1986).

INVESTIGATIONS INTO THE SIDEREAL MOON-RHYTHM, 1970–82

Ulf Abele

Four years of sowing trials were performed by Abele, three as part of his doctorate at Giessen, depicted in Figures 1–4. Each has a linear regression line through the data representing the seasonal trend (Abele 1973,1975). He grew grain crops (barley and oats) in 1970–1971 and root crops (carrots and radish) in 1972 and 1974. Abele designed the trials to give the predicted yield-maxima in rows 4, 8 and 12: the 'fruit-days' for 1970 and 1971, and 'root-days' for 1972 and 1974.

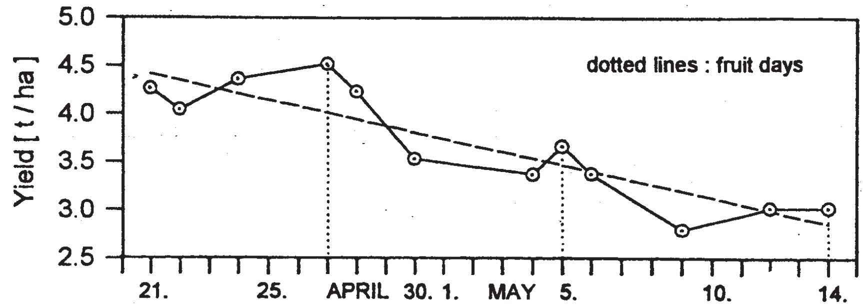

FIGURE 1. Abele, Barley 1970.

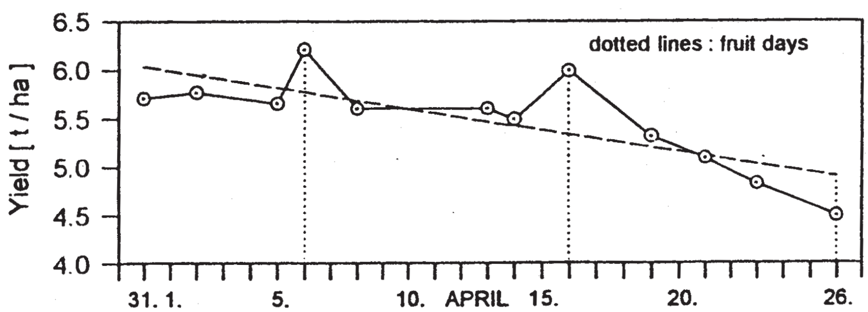

FIGURE 2. Abele, Oats 1971.

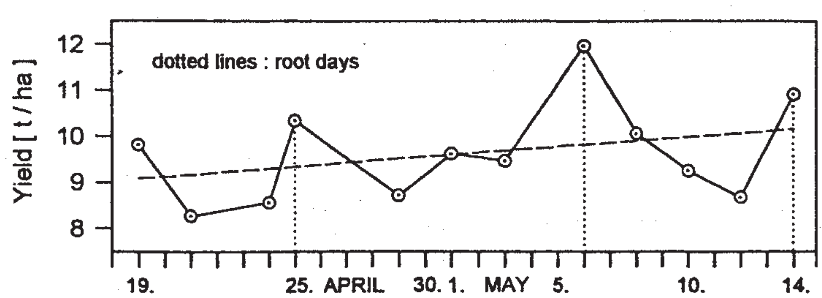

FIGURE 3. Abele, Carrots 1972.

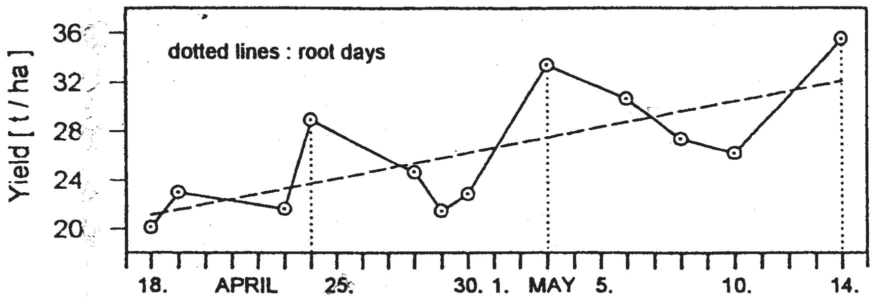

FIGURE 4. Abele, Radish 1974.

This data was reanalysed by subtracting from each set of twelve weight yields the corresponding values on its regression line, then separating the difference values into two groups: the three with predicted yield maxima, and the remaining nine. The results are shown in Table 1. Each of Abele's four trials showed yield maxima where predicted, and yield deviations from the seasonal trend are positive for the trigons predicted and negative for others. The differences of these means are statistically significant except for the 1971 trial. Significance was investigated by a t-test such that the hypothesis of zero difference between the group means was rejected with a probability of (1–p)% for a degree of freedom $v = N_1 + n_2 - 2$, if the experimental t-value > t_v ,p. Hence for Abele's trials, the group means differ with a high probability of 95%–99%. It is preferable to use groups of more than three for statistical treatment, as a t-test requires that the two groups being compared are normally distributed, and one cannot ascertain this from merely three values. These trials were therefore combined with those for grain yields (1970 and 1971) and those for root crop yields (1972 and 1974).

TABLE 1

Four years trials of the 'Thun effect' by Abele.

Crop	Data	Mean Y	Trigon predicted ($t\ ha^{-1}$)	Other rows ($t\ ha^{-1}$)	t-value
Mean yields and yield deviations					
Barley	1970	3.67	0.29 ± 0.15	–0.10 ± 0.21	2.6 > t_{10}, 0.05
Oats	1971	5.46	0.22 ± 0.45	–0.07 ± 0.15	1.6 > t_{10}, 0.10
Carrot	1972	9.62	1.29 ± 0.60	–0.43 ± 0.61	3.9 > t_{10}, 0.005
Radish	1973	26.25	4.81 ± 1.05	–1.61 ± 2.10	4.7 > t_{10}, 0.001
Combined data with yield deviations normalized to a mean of 100					
Barley + oats	1970, '71		5.7 ± 6.5 (n = 6)	–1.9 ± 4.4 (n = 18)	3.1 > t_{22}, 0.01
Carrot + radish	1972, '74		15.9 ± 5.8 (n = 6)	–5.3 ± 7.3 (n = 18)	6.2 > t_{22}, 10^{-4}

To do this, the yield-values were first transformed to the same mean of 100, enabling the data-sets to be combined. They were then corrected for seasonal-trends by subtracting out the linear regression lines as before. These combined sets gave the yield data as shown in Table 1.

Statistically, the grain yield excess was significant at $p = 0.01$, while the root-crop yield over Abele's two trials was significant at $p = 0.0001$. Expressing the mean yield excess in the predicted trigon as a percentage, for Abele's two grain crop trials, the 'fruitday' trigons showed a mean yield excess of 7% over the others (5.7+1.9%), while his two root crop trials averaged an excess of 21 % (15.9 + 5.3%) from sowings in the predicted trigon as compared with sowings at other times. Spiess viewed these results as positive (Spiess, 1994).

English data

Figure 5 reproduces a British result from a 1976 sowing trial (Kollerstrom, 1977; Kollerstrom, 1993; Kollerstrom & Staudenmaier, 1998). Twenty four rows of potatoes were sown over 2 months by a grower in Sussex and showed yield maxima for the root-day sowings: their mean yields were 30% in excess of sowings on other days. The crop yields per row were expressed by the ratio, weight yield of potatoes grown divided by weight of potatoes sown, where 4.6 was its mean value. The seasonal trend was modelled by a five point moving average. After subtracting this out, grouping the data by root-day sowings versus all the others gave 1.5 ± 0.9 ($n = 5$) for root-days and -0.5 ± 1.1 ($n = 15$) for other sowings. This excess was significant at $3.5 > t_{18}$, $p = 0.002$, a highly significant result. Another U.K. report from the 1970s described an experiment from sowing 36 rows of lettuce over three sidereal months, by a different investigator, and again a highly significant positive result was obtained, from yield excesses in leaf-day sowings as predicted (Bishop, 1977).

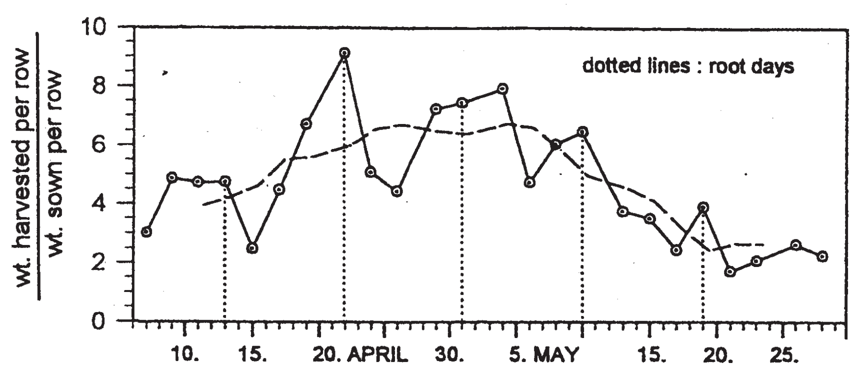

FIGURE 5. Muntz/Kollerstrom, Potatoes 1976.

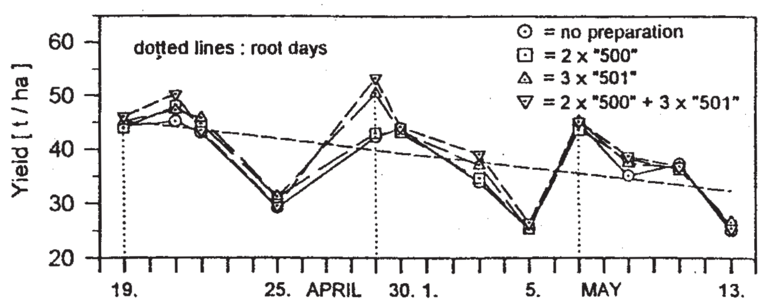

FIGURE 6. Lücke, Potatoes 1980.

Lücke

Two years of trials 1979–80 were conducted by Lücke, as part of his doctorate thesis (Lücke, 1982). Figure 6 shows his 1980 potato trial yields, where the predicted maxima (root-day trigons) occur at positions 1, 5 and 9. Four sets of 12 rows were sown over one month, three of them receiving treatment with sprays (Figure 6). As can be seen from the graph, the mean yields per set were very similar. Spiess regarded the results obtained as non-significant (Spiess, 1994).

Lücke obtained 48 potato row yields from his 1980 field trial, then used a single linear regression line to model their seasonal trend. In this analysis residuals (Y_1) were obtained by subtracting this trendline from the individual row-yields. Their mean yield was 3.85 t ha^{-1}. Separating the data-points into the two groups, root-trigon versus the others, gave a yield increase of 0.53 ± 0.49 t ha^{-1} ($n = 12$) for the root-day sowings and a yield decrease of -0.18 ± 0.61 t ha^{-1} ($n = 36$) for all other rows, corresponding to a total excess yield of 18%. The t-value was $3.6 > t_{46}$, so that the predicted effect was significant at $p = 0.001$. Lücke's earlier 1979 trial using oats had one of its three fruit-day sowings omitted, preventing statistical treatment.

Others

Three years of potato trials by Graf for her doctorate thesis at the Zurich ETH, investigating the sidereal trigons, obtained equivocal results (Graf, 1977). Graf & Keller commented that Graf's 1975 growth chamber experiment with radishes on biodynamically treated soil gave a yield excess of 20%, significant at $p < 0.001$, for yields from root-day sowings as compared with the others, for a total of 264 radish grown (Graf & Keller, 1979). A review of the evidence by Dubrov alluded to "very strict standardised experiments …" as having shown how lunar influence worked in plant growth and development (Dubrov, 1996).

He referred to Kolisko, but also to the Thun-Heinze and Graf-Keller reports, both published in 1979.

THE SPIESS EXPERIMENTS

Since 1984, reports of the negative results obtained in an experimental investigation of the lunar-sidereal 'trigons' in crop yield by Spiess have obtained widespread publicity and a major biodynamic textbook discussed the Spiess conclusions as having refuted the 'Thun effect' (Koepf *et al.,* 1996). It seems, however, that the negative nature of these results (Spiess, 1994) has been exaggerated. The effect present in the Spiess data appears as of relatively small amplitude, though in the case of his carrot data it achieved a high level of statistical significance if the three years of his trial were pooled together. For one year of his radish trials (1982), two sets of radish were sown sequentially, one with added fertilizer and the other without, where the sidereal rhythm was more strongly present in the data-set without added fertilizer.

Spiess developed a distinctive two stage method of data transformation, here applied to results of his 1982 radish sowing trial and his three years of carrot trials, 1978–80. The discussion here is thus confined to his radish and carrot yields (Spiess, 1990b). His winter rye sowing trials (Spiess 1990a) have not been analysed because seeds sown in winter-time could fail to germinate within a day of being sown. It is crucial to the theory of these experiments, that germination occurs on the day of sowing.

Radish trials, 1982

To compare the yields (Y) of two or more trials, normalized yield values $Y_1 = 100Y/Y_{mean}$ were used. For investigating whether lunar-monthly rhythms are present in crop yield data, it is, in general, necessary to allow for the seasonal or year trend, as this may be larger in magnitude than rhythms of a monthly nature. To do this, one can put second-order regression lines through the data, i.e. best-fit parabolas, as did Spiess, or one can apply a moving average. Such a moving average here includes two sowings before a given date and two after, taking the mean of these five values. The latter method was used here (Kollerstrom & Staudenmaier, 2001). Both techniques, a regression line, plus a five-point moving average, are illustrated in Figure 7, applied to the Y, data of the 1982 radish experiment.

The trend line values (T) are then subtracted out from the Y_1 (i.e., $Y_2 = Y_1 - T$). These Y_2 data-points. That subtraction gives a new data-set, which is called Y_2 (i.e., $Y_2 = Y_1 - T$). These Y_2 data points are used to test for lunar-sidereal rhythms present in final crop yield. We used this methodology as

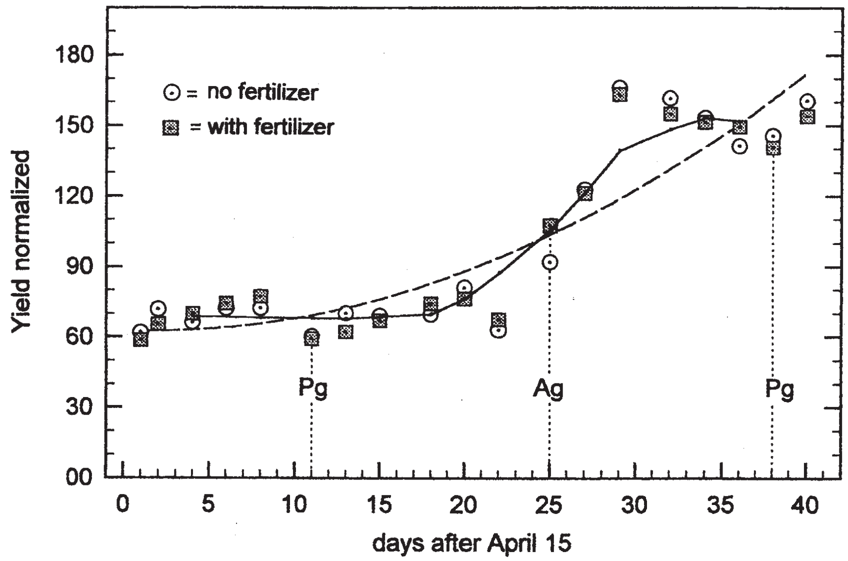

FIGURE 7. Spiess, Radish 1982.

applied by Spiess, but modelling the seasonal trend differently as described, to go from Y_1 to Y_2. As Figure 7 indicates, the way one allows for seasonal trend can affect final values considerably. The 1982 experiment involved one lot of sowings per Moon-constellation (i.e. 12 per sidereal month) over a 39-day period, so that 19 rows were sown in all. Two separate sets were conducted in parallel, one with added fertilizer and one without. The experiment had trandomized, complete block designs with four replications4 at each sowing (Koepf *et al.,* 1996).

The next step involved making a separation within the Y_2 data-set. The hypothesis tested was that one ‘trigon’, in this case root-day sowings, gives a better yield than do the others. The data was therefore separated into two groups, root-day sowings and the rest. Spiess separated the data into four groups, by the four trigons, performing an analysis of variance. These two approaches are both valid, but the former may have simpler statistics. Separating the Y_2 yield values into these two groups gave the results shown in Table 2.

TABLE 2

Mean yield-deviations (Y_2) normalized to a mean of 100 for Spiess's two 1982 radish trials, root-trigon sowings vs. others.

	Root-days	Other rows	t-value
Trial I (no fertilizer)	7.6 ± 17 (n = 3)	–2.4 ± 10 (n = 12)	1.7 > t_{13}, 0.1
Trial II (fertilizer)	4.7 ± 17 (n = 3)	–0.4 ± 7 (n = 12)	0.8 > t_{13}, 0.5

These Y_2 mean values are percentages, because the Y_1 groups have means of 100. Thus the no-fertilizer group had 7.6% excess for the root-day yields, while the other rows had 2.4% deficit, so that, overall, the root-day sowings achieved 10% more in weight yield than did the other sowings. Owing to the large scatter in the data (Figure 7) the effect was not statistically significant (t = 1.7, p = 0. 1). It is preferable that mean yields should not increase so sharply during the course of an experiment. Even with a 10% excess as predicted, this increase prevented the data from attaining significance. Trial II with fertilizer did not show a statistically relevant yield distribution.

Thun has claimed that the sidereal trigons show up best if crops are not treated with fertilizer (Thun, 1964), which Graf in her PhD at Zurich claimed to have confirmed (Graf, 1977). Though of smaller magnitude than others have found earlier from investigations of the 'Thun effect', this yield excess may nonetheless be large enough to be of interest to commercial growers, as the result of a well-designed and carefully performed test of the 'Thun-effect'.

Carrot trials, 1978–80

This same technique of data analysis was applied to the three years of carrot sowing data, which Spiess performed in 1978-80 (Spiess, 1993, 1994). For these three years of trials the same experimental procedure was used, sowing approximately once per Moon-zodiac constellation as for the 1982 radish trial. The trials extended over a month, which meant that 14–15 rows were sown each year. However, the last six rows sown in 1979 had to be omitted, owing to a two-week discontinuity in the data.

The carrot trials achieved a more uniform growth than did Spiess's radish trials. An indicator of how well trials have been conducted is the standard deviation of the yields expressed as a percentage of the mean. This is shown Table 3, where the variance of the carrot-yields is compared with that of the radish-trial discussed above. For whatever reason, these are a mere one-third the value for the carrot trials, so that better results might be expected from analysing his carrot-data. Five-point moving average trendlines were put through these

TABLE 3

Standard deviations in the Y_1 and Y_2 data groups of Spiess trials here analysed.

Crop	Date	Y_1 group	Y_2 group
Carrot	1978	100 ± 11.8 (n = 14)	–0.3 ± 2.8 (n = 10)
Carrot	1979	100 ± 8.9 (n = 10)	0.4 ± 6.8 (n = 6)
Carrot	1980	100 ± 10.7 (n = 15)	–0.3 ± 4.3 (n = 11)
Radish	1982	100 ± 40.0 (n = 38)	0.1 ± 10.2 (n = 30)

groups as before, subtracting which gave the Y_2 values. The Table shows how two-thirds of the variance is removed by subtracting out the seasonal trend line, passing from Y_1 to Y_2, also how the number of rows per group was reduced in passing from Y_1 to Y_2 values, by use of the moving average.

The transformed carrot data 1978–80 were separated as before into two groups, root-day sowings and others. Over the three years of these trials, the Y_2 root-day values averaged 6.3 ± 4.1 (n=5) while other sowings averaged -1.6 ± 2.9 (n=22), an 8% excess, with a t-value of 5.4, as was highly significant ($p = 0.001$).

DISCUSSION

In the 1990s, discussions in print of the biodynamic calendar in Europe, America and New Zealand, have alluded to the experiments conducted by Spiess as having tested the Thunhypothesis and failed to replicate it (e.g., N.Z. Biodynamic Association, 1989; Llewellyn, 1993). Enjoying widespread publicity, and published by the Forschungsring of the German biodynamic movement, the Spiess results have worked to discredit biodynamic calendars.

It appears, however, that although the experiments were well designed, this was not matched by a corresponding care in the data analysis. There were two other radish trials, which Spiess performed in 1979 and 1980, over 30-day periods, where in the first case yields increased by a factor of seven from start to finish of the experiment, and in the second case they more than doubled. But, in experiments conducted over only one month, containing such large seasonal trends within the data, it is unrealistic to expect lowamplitude sidereal rhythms to be detectable. The Dottenfelderhof farm near Frankfurt, where the trials were performed, is in a quite highly industrialized area of Germany, as could here be relevant.

While the Spiess sowing trials and methodology had commendable features, use of parabolic curves to model the seasonal trend was inappropriate, and the alternative here used of moving averages to model the seasonal trend gave Y_2 element-means of considerably smaller standard deviations. Results published to date suggest that the 'Thun-effect' is a testable and verifiable hypothesis. The current analyses endorse Spiess's general conclusion that 'lunar factors' may have a practical significance for agriculture.

References

Abele, U. (1973). *Vergleichende Untersuchungen zum konventionellen und biologisch-dynamischen Pflanzenbau unter besonderer Berucksichtigung vom Saatzeit und Entitaten.* PhD thesis, University of Giessen, Germany.

Abele, U. (1975). Saatzeitversuch zu Radies. *Lebendige Erde*, **6**, 223–225.

Bacon, F. (1627). Sylva Sylvarum. In: *The Works of Francis Bacon*, Vol.2. (J. Spedding ed.), p. 636, Longmans; London 1887.

Beeson, C. (1946). The moon and plant growth. *Nature*, **158**, 572–3.

Bishop, C. (1977). Moon influence in lettuce growth. *The Astrological Journal*, **10**(1), 13–15.

Bockemühl, J. (1985). Elements and ethers: modes of observing the world. In *Towards a Phenomenology of the Etheric World* (J. Bockemühl, ed.) pp. 1–68. Anthroposophical Press; New York, U.S.A.

Brown, F. (1960). The rhythmic nature of animals and plants. *Cycles*, **April**, 81–92.

Brown, F. & Chow, C.S. (1973). Lunar-correlated variations in water uptake by bean seeds. *Biological Bulletin*, **145**, 265–278.

Dubrov, A. (1996). *Human Biorhythms and the Moon.* Nova Science Publishers; New York, U.S.A.

Edwards, L. (1993). *The Vortex of Life, Nature's Patterns in Space and Time.* Floris Press; Edinburgh, Scotland.

Graf, U. (1977). Darstellung verschiedener biologisher Landbaumethoden und Abklarung des Einflusses kosmischer Konstellationen auf das Pflanzenwachstum, PhD thesis, Zurich Technical College, Switzerland.

Graf, U. & E.R. Keller (1979). Zusammenhange zwischen kosmischen Konstellation und dem Ertrag landwirtschaftliche Kulturplanzen. *Landwirtschaftliche Monatschefte*, **57**, 325–336.

Hachez, M. (1935). The significance for seed-germination of the passage of the Moon through the constellations of the zodiac. *Anthroposophical Agricultural Foundation, Notes & Comments*, **IV**, 283–289.

Koepf, H. (1989). *The Biodynamic Farm, Agriculture in the Service of the Earth and Humanity.* Anthroposophic Press; New York, U.S.A.

Koepf, H., Schaumann, W. & Haccius, M. (1996). *Biologische-Dynamische Land Wirtschaft.* Darmstadt, Germany.

Kolisko, E. (1936). *The Moon and the Growh of Plants.* Stroud, Gloucester, U.K.

Kollerstrom, N. (1977). Zodiac rhythms in plant growth: potatoes. *Mercury Star Journal,* London, **III**, 50–53.

Kollerstrom, N. (1980). Plant response to the synodic lunar cycle: A review. *Cycles, Bulletin of the Foundation for the Study of Cycles*, **31**(3), 61–63.

Kollerstrom, N. (1993). Testing the lunar calendar. *Biodynamics*, **Winter 1993**, 44–48.

Kollerstrom, N. & Staudenmaier, G. (1998). Mond-Trigon-Wirkung: eine statistiche Auswertung. *Lebendige Erde*, **November 1998**, 478–483.

Kollerstrom, N. & Staudenmaier, G. (2001). Mond in Tierkreis: anders rechnen – andere Ergebnisse. *Lebendige Erde*, **January 2001**, 48–49.

Llewellyn (1993). Llewellyn's (1993). *Lunar Organic Gardener.* Llewellyn; St. Paul, Minnesota, U.S.A.

Lücke, J. (1982) *Untersuchungen uber den Einflus der Saatzeiten nach dem Siderischen Kalendar auf Ertrag und Qualitat von Hafer und Kantoffeln*. Dissertation, Universität Giessen 1982.

Mather, M. (1942). The effect of temperature and the Moon upon seedling growth. *Journal of the Royal Horticultural Society*, **67**, 264–70.

Maw, M. (1967). Periodicities in the influences of air ions on the growth of garden cress. *Canadian Journal of Plant Science*, **47**, 499–505.

New Zealand Biodynamic Association (1989). *Biodynamics, New Directions for Farming and Gardening in New Zealand*, Random Century; Auckland, New Zealand.

Rossignol, M., Tizroutine, S. & Rossignol, L. (1990). Lunar cycle and nuclear DNA variations in potato callus. In *Geo-Cosmic Relations.* (G. Tomassen, ed.) pp. 116–126. Pudoc; Wageningen, Holland.

Sattler, F. & Wistinghausen, E. (1989, English trans. 1992). *Biodynamic Farming Practice.* Cambridge University Press; Cambridge, U.K.

Spiess, H. (1990a). Chronobiological investigations of crops grown under biodynamic management. 1. Experiments with seeding dates to ascertain the effects of lunar rhythms on the growth of winter rye. *Biological Agriculture & Horticulture*, **7**, 165–178.

Spiess, H. (1990b). Chronobiological investigations of crops grown under biodynamic management II. On the growth of little radish. *Biological Agriculture & Horticulture*, **7**, 179–89.

Spiess, H. (1993). Haben Lunare Rhythmen Bedeutung fur den Ecologishen Landbau? *Stiftung Ecologie und Landbau*, **42**, 397–403.

Spiess, H. (1994) *Chronobiologische Untersuchungen mit besonderer Berucksichtigung lunarer Rhythmen im biologische-dynamischen Pflanzenbau,* Darmstadt; 2 vols, I 'Band 3' of 258 pp., and II 'Band 4 – beschreibung der einzelergebnisse' of 319 pp., the data.

Steiner, R. (1993). *Lectures on Agriculture*, 1924. translation by C. Creger & M. Gardner, Biodynamic Farming and Gardening Association; Kimberton, U.S.A.

Thun, M. (1964). Nine years observation of cosmic influences on annual plants. *Star and Furrow*, **22** (translated from *Lebendige Erde,* Jan/Feb. 1963).

Thun, M. & Heinze, H. (1979). *Mondrhythmen im Sidetischen Umlauf und Pflanzenwachstum.* Darmstadt, Germany.

Thun, M. (1991). *Work on the Land and the Constellations.* Lanthorne Press; Launceston, U.K.

Thun, M. (1999). *Gardening for Life – the Biodynamic Way.* Hawthorne Press; Stroud, U.K.

Thun, M. (2001). *Working with the Stars, a Biodynamic Sowing and Planting Calendar.* 26th edn. Lanthorne Press, Launceston, U.K.

Wachsmuth, G. (1932). *The Etheric Formative Forces in Cosmos, Earth and Man.* Anthroposophic Press; London, U.K.

Wildfeuer, S. (1986). *Stella Natura, The Kimberton Hills Agricultural Calendar,* 19th edn. Kimberton Hills Publications; Kimberton, U.S.A.

(*Received 25 January 2001; accepted 5 August 2001*)