

半干旱地区不同地膜覆盖时期对土壤氮素有效性的影响

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摘要: 在年降水量 415 mm 的半干旱地区黄绵土上, 以春小麦为供试作物进行大田试验, 研究地膜覆盖(包括不覆膜、播种后覆膜 30 d、覆膜 60 d 和全程覆膜)对土壤水分、温度和氮素有效性的影响。结果表明, 覆膜对 2 m 土层贮水量基本没有影响, 能显著提高 0~20 cm 土层的含水量; 覆膜对 5 cm 处土壤温度的影响呈“U”型变化, 即在作物生长前期和后期影响显著, 中期影响较小; 覆膜能增加土壤呼吸和有机氮的矿化, 因而显著影响土壤剖面中 NO_3^- -N 的累积: 表现为在收获时覆膜 30 d 和 60 d 处理剖面中 NO_3^- -N 的累积明显下降, 而全程覆膜处理剖面中 NO_3^- -N 的累积显著增加, 在覆膜的基础上施用氮肥, 这种作用会更加突出。显然全程覆膜易造成有机质的大量矿化和 NO_3^- -N 的淋溶损失。

关键词: 旱地土壤; 地膜覆盖; 土壤养分; NO_3^- -N 累积

Effects of plastic film mulching periods on the soil nitrogen availability in semiarid areas

LI Shi-Qing, LI Feng-Min, SONG Qiu-Hua, WANG Jun (State Key Laboratory of Arid Agroecology, Lanzhou University, Lanzhou 730000, China). *Acta Ecologica Sinica*, 2001, 21(9): 1519~1526.

Abstract: A field experiment was carried out on cultivated loessial soil in semiarid areas with 415 mm precipitation and spring wheat (*Triticum aestivum* L.) used as an indicating crop to study the effects of the plastic mulching periods on the soil nitrogen availability. The experiment had three factors and they were water storage in soil profile before sowing, plastic film mulching period and nitrogen fertilization. The water storage in soil profile before sowing had two levels under each of which there were no mulching, 30-day mulching, 60-day mulching and full-growing-period mulching after sowing. Under each mulching period there were two rates of nitrogen fertilization and the rates were 0 kg/hm² and 75 kg/hm². So the experiment had a complete design with 16 treatments, and all the treatments were replicated three times.

The results of the experiments showed that plastic film mulching significantly increased water contents of surface soil (the average water content of 0~20 cm soil with plastic film mulching was 3.2% higher than that without mulching during the period of crop growth and the difference between the two reached a significant level), but it made the water contents of subsoil soil decrease, so the water storage of 0~200 cm soil with plastic film mulching was basically equal to that without mulching.

The plastic film mulching could increase soil temperature, and the effect of plastic film mulching on the soil temperature at the depth of 5 cm was related with crop growth. Because there was low crop coverage during the early stage of crop growth (the 1st~30th day after sowing), plastic film mulching could sig-

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nificantly increase the soil temperature; The crop coverage increased during the middle stage of crop growth (the 30th~90th day after sowing) and thus temperature-increasing effect of plastic film mulching became weak; During the latter stage of crop growth (the 90th~120th day after sowing), crop leaves drooped and crop coverage declined, and thus the temperature-increasing effect of plastic film mulching became strong. So the temperature-increasing effect of plastic film mulching showed a U-shape pattern with crop growth.

Plastic film mulching inevitably resulted in accelerating the decomposition of soil organic matter. The value of soil respiration (the amount of CO_2 releasing from soil) directly measured in situ can reflect the rate of soil organic matter decomposition. According to the experiment results, plastic film mulching could significantly increase the amount of CO_2 releasing from soil, the average released CO_2 amount with plastic film mulching was $251.5 \mu\text{g}/\text{cm}^3$ higher than that without mulching and this difference reached a significant level of $p < 0.01$. The plastic film mulching with nitrogen fertilization could intensify the decomposition of soil organic matter due to the priming effect of nitrogen fertilizers.

Nitrogen fertilization and plastic film mulching significantly affected the accumulation of nitrate nitrogen in soil profile ($p < 0.01$). No matter in which treatment, the amount of accumulated nitrate nitrogen declined as wheat growth advanced. The difference of accumulated nitrate nitrogen between nitrogen fertilization and no-nitrogen fertilization correlated with the stages of wheat growth and the film mulching period. On the 30th day and 60th day after sowing, the amount of accumulated nitrate nitrogen with the plastic film mulching was significantly higher than that without mulching, but the amount of accumulated nitrate nitrogen in the plots for 30-day mulching was lower than that mulched for all the growing period on the 60th day after sowing; On the 90th day after sowing and at the time of wheat harvesting, the amounts of accumulated nitrate nitrogen in the plots for 30-day mulching and 60-day mulching were not only lowest, but also did not differ much earth other. After wheat harvesting, the amounts of accumulated nitrate nitrogen with 30-day mulching and 60-day mulching without nitrogen fertilization were $29.0 \text{ kg}/\text{hm}^2$ and $14.9 \text{ kg}/\text{hm}^2$ in 0~100 cm soil profile lower than that without mulching, respectively. The amount of accumulated nitrate nitrogen in the plot of full-growing-period mulching was $9.4 \text{ kg}/\text{hm}^2$ higher than that without mulching plot. The amounts of accumulated nitrate nitrogen with 30-day and 60-day mulching, with nitrogen fertilization were $17.1 \text{ kg}/\text{hm}^2$ and $5.3 \text{ kg}/\text{hm}^2$ lower that without mulching, respectively. The amount of accumulated nitrate nitrogen with the full-growing-period mulching was $88.9 \text{ kg}/\text{hm}^2$ higher than that without mulching while nitrogen fertilier input. The effects of the plastic film mulching on nitrate nitrogen in soil profile related with the uptake of soil nitrate nitrogen by wheat and the mineralization of soil organic nitrogen. On one hand, 30-day mulching and 60-day mulching promoted the growth of wheat and the uptake of nitrate nitrogen by wheat during the early growing period, on the other hand, because of without mulching during 30~90(126) days for 30-day mulching treatment or 60~90(126) days for 60-day mulching treatments, the mineralization of soil organic nitrogen became weak and thus the amount of accumulated nitrate nitrogen in soil profile decreased significantly. The temperature and soil moisture in the full-growing-period mulching treatment still are suitable for the mineralization of soil organic nitrogen during 60~126 days, at the same time the requirement of wheat for nutrient decreased and the nutrient uptake ability became weak, so a lot of nitrate nitrogen was accumulated in soil profile. While plastic film mulch as well as nitrogen fertilization were practices, the amount of accumulated nitrate nitrogen increased significantly due to the priming effects of nitrogen fertilizers on the mineralization of soil organic nitrogen.

Because during latter stage of wheat growth the roots of spring wheat had weak ability to uptake nitrate nitrogen, and in the latter stage of wheat growth there was rich rainfall, the amount of accumulated nitrate nitrogen in full-growing-period mulching treatment could leached very easily. Obviously, the plastic film mulching through full-growing-

period had some certain limitations. It could result in the decrease of wheat yield because of limiting water and nutrient conditions during latter stage of wheat growth (our experiments described in this paper and our former experiments have proved this result), and promote excessive mineralization of soil organic nitrogen during latter stage of crop growth. Therefore, long-term plastic film mulching is disadvantageous for sustainable agricultural production.

Key words: dryland soil; plastic film mulching; soil nutrients; accumulation of nitrate nitrogen

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地膜覆盖在广大北方旱地农业区被广泛推广和应用, 这一技术已成为该地区农业生产再上新台阶的重要措施之一^[1,2]。地膜覆盖增产的机制首先在于改善了土壤生态环境, 即水、热状况^[1,3,4], 进而活化土壤养分^[5], 使养分有效性和水分利用效率提高^[6]。但生产实践已表明, 地膜覆盖有时因作物生长前期土壤水分和养分耗竭严重, 后期会出现严重的脱水、脱肥现象^[1,7], 导致减产^[1]; 同时, 地膜覆盖的增产作用在一定程度上是以耗竭土壤有机物质和养分为代价的^[8,9]。因此, 如果地膜覆盖技术应用不当, 长期连续或全程覆膜不仅导致产量下降, 而且也将恶化土壤生态条件, 使土壤肥力下降, 难以持续高产。因此, 研究覆膜对土壤养分有效性的影响, 对指导合理应用地膜具有重要的理论和实践意义。

1 材料和方法

1.1 试验区的自然条件

大田试验于 1999 年 3~7 月份在甘肃省定西县唐家堡农业试验站进行。该地区为典型的半干旱黄土丘陵沟壑区, 海拔 1970 m, 年均气温 6.2℃, 年降水量 415 mm, 且多集中于 7~9 月份, 与春小麦的生育期不吻合。该区年辐射总量 5898 MJ/m², 年日照时数 2500 h, ≥10℃积温 2075.1℃, ≥5℃积温 2591.8℃, ≥0℃积温 2787.7℃, 无霜期 140 d, 作物一年一熟。试验区土壤为黄绵土, 肥力中等, 基本性质见表 1。土壤容重 1.25 g/cm³, 地下水埋深大于 10 m, 不具备补给能力。天然降水是该区作物生产的主要水源, 降水少, 且变率大、分布不均、有效性差。

表 1 供试土壤的基本理化性质

Table 1 Basic physical and chemical properties of soil used in the experiment

土层 Layer (cm)	有机碳 Organic C(g/kg)	全氮 Total N (g/kg)	C/N	有效磷 Available P (μg p/kg)	全磷 Total p (g p/kg)	机械组成(g/kg)			质地 Textural classification
						Particle size analysis			
						2.0~0.02mm	0.02~0.0002mm	<0.002mm	
0~20	8.53	0.955	8.9	11.0	0.952	479.4	352.8	167.8	粘壤土 Clay loam
20~40	7.37	0.785	9.4	2.2	0.910	395.1	382.1	222.8	粘壤土

1.2 试验方法

试验共设底墒、覆膜和施氮 3 个因子, 底墒设低、高 2 个水平, 每一底墒下设不覆膜, 覆膜 30 d, 60 d 和全生育期(简称全程)等 4 种方式, 各种覆膜方式下又设不施和每公顷施 75 kg N 2 个水平, 组成完全方案, 共 16 个处理, 3 次重复, 小区面积 18.5 m²。底墒处理集中成块, 覆膜方式在块内随机排列, 在不同覆膜方式下, 施氮处理又随机排列。以含 N 46% 的尿素为氮源, 以含 P₂O₅ 16% 的普通过磷酸钙为底肥, 每公顷施 750 kg 过磷酸钙。两种肥料在播前均匀撒施后, 翻入土壤, 耙平覆膜后, 用穴播机穴播。供试春小麦品种为陇春 8139-2。

播前对高底墒处理每小区灌水 1.6 m³, 低底墒处理每小区灌水 1.0 m³, 灌后待地表干至能作业播种时多点采集土壤样品, 测定 0~200 cm 土层贮水量。经测定高底墒处理贮水量为 351.7 mm, 低底墒处理为 310.5 mm。3 月 22 日播种, 1999 年 7 月 27 日收获, 全生育期 126 d, 共降水 239.9 mm。

自播种之日起在覆膜和不覆膜处理小区中埋入地面温度计, 每天在 8:00, 14:00, 18:00 定时观测

记录,测定深度为5 cm处的土壤温度,日均地温为每日3次与次日8:00观测值的平均值。播种后每隔30 d从2个重复中采土,采样深度为200 cm,每20 cm取1层,进行土壤养分分析。

收获时,除去4周保护区,每小区实收面积13.21 m²,分籽粒和茎叶两部分计产。同时取分析样,测定籽粒和茎叶含氮量。

另外,为了测定覆膜和施氮对土壤性质的影响,在进行小区试验的同时,还安排了微区试验。试验设不覆膜不施氮、不覆膜施氮、覆膜不施氮和覆膜施氮4个处理,微区面积8.1 m²。微区不种作物,但在施肥、覆膜等处理前也进行了补充灌水。每微区灌水0.5 m³。覆膜前经测定0~200 cm土层贮水量为356.3 mm。

在播种后60 d、90 d和收获时,用CJL-301型CO₂分析仪(CID Inc, USA)测定微区土壤的呼吸,从早上8:00开始,每隔2 h测1次,共测6次,测定时采样时间为14 min,换气速率为1.0 L/min。

1.3 土壤和植株分析

土壤水分用烘干法(105℃下烘12~14 h),有机质用重铬酸钾外加热法^[10],全氮用开氏法^[11],全磷用HClO₄-H₂SO₄法^[12],有效磷用Olsen法^[12],机械组成用吸管法,微生物体氮用熏蒸-培养法^[13],土壤铵、硝态氮用Bremner法浸取(1 mol/L KCl 50 ml+5 g 风干土壤,振荡1 h 过滤)后^[14],流动注射分析仪测定^[15]。测出土壤含水量和铵态氮、硝态氮后,根据土壤容重1.25 g/cm³换算成0~200 cm土层的贮水量和0~100 cm土层的铵态氮、硝态氮贮存量。植株全氮用Tekmar-10型粉碎机粉碎后,浓H₂SO₄-H₂O₂消煮^[22],开氏1030自动定氮仪测定。试验结果用SAS软件进行差异显著性检验和多重比较^[16]。

2 研究结果

2.1 地膜覆盖对土壤水分和温度的影响

作物生长期4次测定平均值表明,虽然地膜覆盖显著增加了表层土壤含水量(作物生长期覆膜后0~20 cm土层含水量比不覆膜平均高出3.2%,差异达显著水平),但由于覆膜后深层土壤含水量减少^[7],因而覆膜和不覆膜2 m土层的贮水量基本一致。作物生长期(特别是苗期)耕层土壤含水量的改善,对促进作物早萌发、早出苗和苗期茎叶,特别是根系的发育及土壤养分的有效化和作物吸收具有重要作用。

地膜覆盖增产的另一重要作用是提高了土壤温度^[13,14],特别是能显著增加耕层5 cm处的土壤温度(图1),地膜覆盖对温度效应的大小与作物生长期有关:在生育前期(1~30 d),由于地面覆盖度低,增温效应显著;生长中期(30~90 d),由于地面覆盖度增加,增温作用减弱;生长后期(90~126 d),由于叶片干枯,地面覆盖度又减小,增温效果又增加,全生育期地膜覆盖的增温效应呈“U”型变化趋势(图1)。对春小麦,播种后前期的土壤增温对早出苗和促进苗期生长具有重要作用^[1],观察表明覆膜比不覆膜处理的早出苗7~8 d,还有利于增加根系对养分的吸收,促进早分蘖、早拔节,减少分蘖与主茎对水、肥的竞争,增加有效分蘖^[1]。但后期增温,不仅对作物养分吸收、生长和产量的形成没有多大实际意义,而且还会加快土壤有机质的矿化和养分损失。

2.2 地膜覆盖对土壤生物性质的影响

地膜覆盖后,0~20 cm土层温度增高,水分条件改善,微生物活动旺盛,必然会使土壤有机质分解加快。田间原位直接测定的土壤呼吸值(CO₂释放量)可以反映土壤有机质的分解速率。表2表明,覆膜会显著增加土壤中CO₂的释放量,3次测定平均值表明覆膜比不覆膜CO₂释放量增加251.5 μg/cm²,差异达显著水平($p < 0.01$)。在覆膜的基础上施氮,由于氮肥的激发效应^[17],这种作用会更加突出(表2)。地膜覆盖的负效应还可以从微生物体氮的变化粗略看出(表3)。微生物体氮是土壤中活体微生物中的氮素,这一部分氮素与土壤中易矿化的有机氮密切相关,它的高低,可以反映易矿化有机物质的多少^[18]。在覆膜条件下,不论施氮与否,微生物体氮都有下降的趋势,说明覆膜,特别是施氮后,土壤中易矿化有机氮下降。

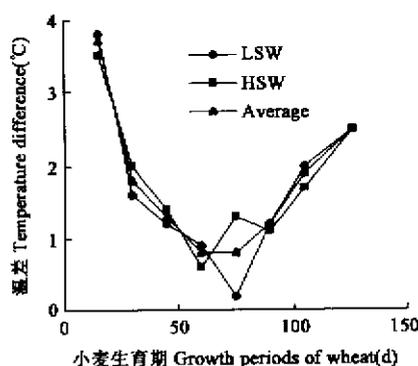


图1 覆膜与不覆膜5 cm深处的土壤温差
Fig. 1 Soil temperature difference between mulching and no mulching in 5 cm depth

趋势,说明覆膜,特别是施氮后,土壤中易矿化有机氮下降。

表 2 覆膜和施氮对裸地土壤呼吸的影响($\mu\text{g}/\text{cm}^3$)

Table 2 Effects of plastic film mulch and nitrogen fertilizer on soil respiration under fallow condition

日期 Date (D/M)	覆膜 Mulch	施氮 N fertilizer kgN/hm ²	测定时间 Measuring time						平均 Average
			08:00	10:00	12:00	14:00	16:00	18:00	
			25/5	不覆 NM	0	82	111	136	
		75	80	141	169	160	136	98	181.0
	覆膜 M	0	216	347	400	367	344	264	323.0
		75	170	309	402	423	468	284	342.7
	不覆 NM		9.5	16.5	21.5	26.0	27.0	23.5	20.7
	覆膜 M		12.3	19.3	25.0	31.8	34.5	30.8	25.6
26/6	不覆 NM	0	97	159	142	188	152	131	144.5
		75	172	155	131	155	129	112	142.3
	覆膜 M	0	1137	558	325	415	571	431	572.8
		75	1017	652	626	753	608	572	704.7
	不覆 NM		17.5	22.0	26.0	30.0	29.5	28.5	25.6
	覆膜 M		21.5	26.5	32.8	39.0	39.0	37.8	32.8
31/7	不覆 NM	0	269	150	184	189	210	183	197.5
		75	257	173	228	176	161	84	179.8
	覆膜 M	0	115	208	118	214	110	163	154.7
		75	908	298	169	371	205	254	367.5
	不覆 NM		22.0	28.0	33.0	36.0	38.7	37.0	32.5
	覆膜 M		25.0	30.0	36.0	43.0	45.4	44.0	37.3

* NM and M represents no mulching and mulching plastic film mulch, respectively.

表 3 覆膜和施氮对土壤微生物体氮的影响($\mu\text{g N/g}$)

Table 3 Effects of plastic film mulch and application of nitrogen fertilizer on soil microbial biomass nitrogen

土地利用 Land usage	底墒 SW	覆膜 Mulch	施氮 N fertilizer (kg N/hm ²)	测定日期 Measuring date		2 次测定 平均 Average
				1999-04-23	1999-05-23	
				种植小麦 Planting	低底墒 LSW	
			75	57.2	45.6	51.4
		覆膜 M	0	67.6	59.6	63.6
			75	49.2	50.0	49.6
	高底墒 HSW	不覆 NM	0	59.8	59.2	59.5
			75	41.8	52.0	46.9
		覆膜 M	0	63.4	56.0	59.7
			75	48.4	39.6	44.0
休闲 Fallow		不覆 NM	0	72.2	64.4	68.3
			75	60.8	62.4	61.6
		覆膜 M	0	79.4	60.8	69.7
			75	61.8	54.0	57.9

SW represents the storage water in profile before sowing; LSW and HSW represents the lower and higher storage water in profile before sowing, respectively; NM and M represents no mulching and mulching plastic film mulch, respectively.

万方数据

2.3 地膜覆盖进程对土壤剖面中矿质氮累积的影响

测定结果表明,无论是从小麦全生育期看,还是从剖面的不同层次看, NH_4^+-N 的含量基本稳定,不同处理对其影响也不显著;而 NO_3^--N 的含量具有很大的时空分异性(表4)。施氮和地膜覆盖显著影响土壤剖面中 NO_3^--N 的累积(显著性均达到1%显著水平),进而影响矿质氮($\text{NO}_3^--\text{N}+\text{NH}_4^+-\text{N}$)的累积。不管哪种处理,随着小麦生育期延长, NO_3^--N 累积量均减少。高底墒处理,由于显著促进了作物前期生长和吸氮量,剖面中矿质氮,特别是 NO_3^--N 累积量低于低底墒处理,从平均看,在30 d、60 d、90 d时高底墒处理的 NO_3^--N 累积量(分别为181.1、107.7和69.7 kg/hm^2)比低底墒(221.6、134.5和91.2 kg/hm^2)分别低40.5、26.8和21.5 kg/hm^2 ,差异均达5%显著水平,但收获(126 d)时,2种底墒处理剖面中累积的 NO_3^--N 基本相同,高底墒和低底墒平均分别为83.7和70.3 kg/hm^2 ,差异不显著。

表4 覆膜和施氮对0~100 cm土层矿质氮累积量的影响($\text{kg N}/\text{hm}^2$)

Table 4 Effects of plastic film mulch and application of nitrogen fertilizer on accumulation of mineral nitrogen in 0~100 cm layer

测定时间(MD)	覆膜 Mulch	施膜 N fertilizer ($\text{kg N}/\text{hm}^2$)	低底墒 LSW			高底墒 HSW			平均 Mean			
			NO_3^--N	NH_4^+-N	Σ	NO_3^--N	NH_4^+-N	Σ	NO_3^--N	NH_4^+-N	Σ	
播前 Before sowing			166.8	108.8	275.6	166.8	108.6	275.6	166.8	108.8	275.6	
30 d	不覆 ^①	0	137.9	93.5	231.4	128.9	77.9	206.8	133.4	85.7	219.1	
		75	239.4	80.9	320.3	149.0	101.1	250.1	194.2	91.0	285.2	
	全程覆膜 ^④	0	221.7	91.8	313.5	186.7	76.7	263.3	204.2	84.3	288.5	
		75	287.3	82.0	369.3	259.6	76.1	335.7	273.5	79.1	352.6	
60d	不覆 ^①	0	120.4	74.8	195.2	78.9	66.9	145.8	99.7	78.9	170.6	
		75	139.0	92.6	231.6	106.9	80.8	187.7	123.0	86.7	209.7	
	覆膜 30 d ^②	0	70.4	83.1	153.5	44.6	62.8	107.4	57.5	73.0	148.5	
		75	151.8	112.6	264.4	106.9	80.8	187.7	129.4	96.7	226.1	
	全程覆膜 ^④	0	138.0	84.9	222.9	91.4	75.8	167.2	114.7	88.2	202.9	
		75	187.1	77.8	264.9	217.4	80.7	298.1	139.3	79.3	218.6	
	90 d	不覆 ^①	0	53.4	67.6	121.0	38.1	64.5	102.6	45.8	66.1	111.9
			75	106.5	67.3	173.8	47.3	83.3	131.1	76.9	75.3	152.2
覆膜 30 d ^②		0	85.2	61.5	146.7	47.3	67.8	115.1	66.3	64.7	131.0	
		75	91.5	57.1	148.6	98.9	58.6	157.5	95.2	57.9	153.1	
覆膜 60 d ^③		0	76.0	59.6	135.6	38.6	81.9	120.5	57.3	70.8	129.1	
		75	111.3	61.4	172.7	49.7	73.6	123.3	80.5	67.5	149.0	
全程覆膜 ^④		0	45.8	54.9	100.7	62.2	70.8	133.0	54.0	62.9	116.9	
		75	159.9	66.5	226.4	175.1	61.2	236.0	167.5	63.9	231.4	
126 d	不覆 ^①	0	82.4	60.1	142.5	47.8	51.8	99.6	65.1	56.0	121.1	
		75	73.9	59.3	133.2	87.4	50.1	137.5	80.7	54.7	135.4	
	覆膜 30 d ^②	0	43.6	51.9	95.5	28.5	51.7	80.2	36.1	51.8	87.9	
		75	52.1	67.2	119.3	75.0	51.8	126.8	63.6	59.5	123.1	
	覆膜 60 d ^③	0	44.9	58.8	103.7	55.4	52.9	108.3	50.2	55.9	106.1	
		75	64.9	60.0	124.9	85.1	51.1	136.2	75.0	55.6	130.6	
	全程覆膜 ^④	0	67.6	63.3	130.9	81.3	47.6	128.9	74.5	55.5	130.0	
		75	132.6	85.3	217.9	208.6	54.3	262.9	170.6	69.8	240.4	
LSD _(0.05)			29.3	ns	25.8	ns	27.5	ns	28.9	ns	26.1	

① No mulching, ② Mulching for 30 days, ③ Mulching for 60 days after sowing, ④ Mulching for whole sowing period. LSW and HSW represents the lower and higher storage water in profile before sowing, respectively.

施氮后, NO_3^--N 大幅度增加(表5)。施氮和不施氮处理 NO_3^--N 累积量的差异与小麦生长时期的关系和覆膜进程有密切关系。不覆膜处理,随着小麦生长,其差异逐渐减小,对覆膜30 d和60 d处理,其差异基本稳定,而对全程覆膜处理,其差异的变化与温度的变化相一致,呈“U”型变化趋势。从覆膜对 NO_3^--N 的影响

看,在 30 d 时,覆膜处理的 NO_3^- -N 累积量显著高于不覆膜处理;60 d 时,覆膜处理的 NO_3^- -N 累积量仍显著高于不覆膜处理,但覆膜 30 d 处理累积的 NO_3^- -N 最少;90 d 和收获(126 d)时,不仅覆膜 30 d 和 60 d 处理的 NO_3^- -N 累积量最少,而且 2 种处理相差不大。从收获后 0~100 cm 土层结果看,在不施氮时,覆膜 30 d 和 60 d 处理土层中累积的 NO_3^- -N 分别比不覆膜的对照减少 29.0 kg/hm² 和 14.9 kg/hm²,全程覆膜(126 d)处理土层中累积的 NO_3^- -N 比不覆膜的对照增加 9.4 kg/hm²;施氮后,覆膜 30 d 和 60 d 处理土层中累积的 NO_3^- -N 分别比不覆膜的对照减少 17.1 kg/hm² 和 5.3 kg/hm²,全程覆膜(126 d)处理土层中累积的 NO_3^- -N kg/hm² 比不覆膜的对照增加 88.9 kg/hm²,对矿质氮累积有相同规律的影响。覆膜进程对土壤剖面中矿质氮,特别是 NO_3^- -N 累积的这种影响与作物对 NO_3^- -N 的吸收和土壤中有有机氮的矿化有关:一方面由于前 30 d 或 60 d 的覆膜促进了小麦生长和对 NO_3^- -N 的吸收,另一方面由于这 2 个处理在 30~90 d(126 d)或 60~90 d(126 d)间又没有地膜覆盖,有机氮的矿化能力减弱,因此土壤剖面中矿质氮,特别是 NO_3^- -N 的累积量显著减少,而对全程覆膜处理,由于在 60~90 d(126 d)耕层土壤水分和温度条件较好,仍有利于有机氮的矿化,而在这一时期,小麦对 NO_3^- -N 的吸收能力减弱,需要量减少^[19],因此在土壤剖面中大量累积矿质氮,特别是 NO_3^- -N。在覆膜的基础上施氮,由于氮肥对有机氮矿化的激发效应^[17], NO_3^- -N 的累积量大幅度增加(表 5)。

表 5 施氮和覆膜对 0~100 cm 土层矿质氮累积量的影响(两种底墒平均,kg N/hm²)

Table 5 Effects of plastic film mulch and application of nitrogen fertilizer on accumulation of mineral nitrogen (averaged with two storage water before sowing)

采样时间 Sampling date	覆膜 Mulch	施氮增加 Increased by N fertilizer			覆膜增加(2 个施氮水平平均) Increased by mulch (averaged by 2 N level)		
		NO_3^- -N	NH_4^+ -N	Σ	NO_3^- -N	NH_4^+ -N	Σ
30 d	不覆膜 ^①	70.8	-1.4	69.4			
	全程覆膜 ^④	69.3	-11.9	57.4	75.0	-6.7	68.3
60 d	不覆膜 ^①	23.3	7.8	31.1			
	覆膜 30d ^②	53.9	23.7	77.6	-8.8	-3.5	-5.3
	全程覆膜 ^④	24.6	-8.9	15.7	47.2	0.3	47.5
90 d	不覆膜 ^①	31.1	9.2	40.3			
	覆膜 30 d ^②	28.9	-6.8	22.1	19.4	-18.6	0.8
	覆膜 60 d ^③	23.2	-3.3	19.9	7.6	-1.5	6.1
	全程覆膜 ^④	113.5	1.0	114.5	49.4	-7.3	42.1
126 d	不覆膜 ^①	15.6	-1.3	14.3			
	覆膜 30 d ^②	27.5	7.7	35.2	-23.0	0.3	-22.7
	覆膜 60 d ^③	24.8	-0.3	24.5	-10.7	0.3	10.4
	全程覆膜 ^④	96.1	14.3	110.4	49.7	7.3	57.0
	LSD _(0.05)	21.7	ns	24.3	19.5	ns	20.9

① No mulching, ② Mulching for 30 days, ③ Mulching for 60 days after sowing, ④ Mulching for whole sowing period

3 讨论

一般在 5~35℃ 范围内,随温度上升,氮素矿化增加,矿化速率常数的温度系数 $Q_{10} = 2^{[20]}$;在水吸力 0.1~15 bar 之间,土壤含水量与矿化量之间几乎呈直线关系^[21]。刘金城等人^[22]的研究结果表明,覆膜栽培条件下,氮素的矿化作用加强,微生物固定作用减弱,而且连续多年覆膜栽培,有效性较高的酸解性氮所占比例减少,非酸解性氮比例增加。由于地膜覆盖后,土壤水分和温度条件改善,土壤呼吸加强,必然导致土壤中有有机氮矿化速率的增加、活性有机氮库(如土壤微生物体氮)的下降^[23]和矿质氮(在旱地土壤中主要是硝态氮)的矿化速率增加。如果作物对矿质氮的吸收速率小于矿化速率,会导致氮的损失。由于在春小麦生长后期根系对养分的吸收利用能力减弱,降水又多,因此全程覆膜在作物生长后期土壤剖面中大量累积的

NO_3^- -N, 非常容易通过淋溶而损失。显然, 全程覆膜具有一定的局限性, 不仅因后期水分和养分限制导致减产(本次试验及前期已进行的试验均说明了这一点), 而且更重要的是全程覆膜, 特别是在作物生长后期, 会增加土壤有机质的过分矿化而导致土壤肥力下降。因此长期覆膜不利于农业生产的持续发展。

参考文献

- [1] Li Feng-Min, Guo An-Hong, Wei Hong. Effects of clear plastic film mulch on yield of spring wheat. *Field Crops Res.*, 1999, **63**:79~86.
- [2] Niu J Y, Gan Y T, Zhang J W, et al. Postanthesis dry matter accumulation and redistribution in spring wheat mulched with plastic film. *Crop Sci.*, 1998, **38**:1562~1568.
- [3] Unger P W. Role of mulches in dryland agriculture. In: Gupta, U. S. ed. *Crop Physiology*. Oxford and IBH, New Delhi. 1975. 237~260.
- [4] Ravi V, Lourduraj A C. Comparative performance of plastic mulching on soil moisture content, soil temperature and yield of rainfed cotton. *Madras Agric. J.*, 1996, **83**:709~711.
- [5] Quezada M, Maria R, Munguia L, et al. Plastic mulching and availability of soil nutrients in cumuber crop. *TER-RA(Mexico)*, 1995, **13**:136~147.
- [6] Mohapatra B K, Lenka D, Naik D. Effect of plastic mulching on yield and water use efficiency in maize. *Annals of Agric. Res.*, 1998, **19**:210~211.
- [7] Zaongo C G L, Wendt C W, Lascano R J, et al. Interactions of water, mulch and nitrogen on sorghum in Niger. *Plant and Soil*, 1997, **197**:119~126.
- [8] 陈锡时, 郭树凡, 汪景宽, 等. 地膜覆盖栽培对土壤微生物种群和生物活性的影响. *应用生态学报*, 1998, **9**(4):435~439.
- [9] 刘小虎, 陈小萱, 须相成. 覆膜栽培条件下有机无机肥施对土壤氮素状况和供应的影响. *沈阳农业大学学报*, 2003(增刊):68~73.
- [10] Nelson D W, Sommers L E. Total carbon, organic carbon, and organic matter. In: Page A. L. ed. *Methods of soil analysis*, part 2. Am Soc of Agron. Madison, Wis, USA. 1982. *Agronomy*, **9**: 539~594.
- [11] Bremner J M, Mulvaney C S. *Nitrogen-total*, part2. Am. Soc. of Agron, Madison, Wis. 1982. 595~624.
- [12] 南京农业大学主编. 土壤农化分析. 第二版. 北京: 中国农业出版社, 1988. 65~229.
- [13] 李世清, 李生秀. 土壤微生物体氮测定方法的研究. *植物营养与肥料学报*, 2000, **6**:74~82.
- [14] Bremner J M. Inorganic forms of nitrogen. In C. A. Black ed., *Methods of soil analysis, part 2*. Am Soc of Agron. Madison Wis. 1965. *Agronomy*, **9**:1179~1237.
- [15] Smith K A, Scott A. Continuous-flow and discrete analysis. In: K. A. Smith ed., *Soil analysis*. Marcel Dekker, Inc., New York. 1983. 115~169.
- [16] 裴喜春, 薛河儒. SAS 及应用. 北京: 中国农业出版社, 1998. 81~82.
- [17] Jenkinson D S, Fox R H, Rayner J H. Interaction between fertilizer nitrogen and soil nitrogen-the so called priming effect. *J Soil Sci.*, 1985, **36**:425~444.
- [18] Myrold D D. Relationship between microbial biomass nitrogen and a nitrogen availability index. *Soil Sci. Soc. Am. J.*, 1987, **51**:1047~1049.
- [19] Fageria N K, Baligar V C, Jones C A. Growth and mineral nutrition of field crops. Marcel Dekker, Inc., USA. 1991. 125~158.
- [20] Stanford G, Frere M H, Schwaninger D H. Temperature coefficient of soil nitrogen mineralization. *Soil Sci.*, 1973, **115**: 321~323.
- [21] Stanford G, Epstein E. Nitrogen mineralization water-relations in soil. *Soil Sci Soc Am Proc.*, 1998, **38**: 103~107.
- [22] 刘金城, 杨晶秋, 白成云. 地膜覆盖下土壤有机质的分解与积累. *华北农学报*, 1991, **6**(1):99~104.
- [23] 宋凤斌. 半干旱地区地膜覆盖增产的土壤生态学基础. *吉林农业大学学报*, 1991, **13**(2):4~7.